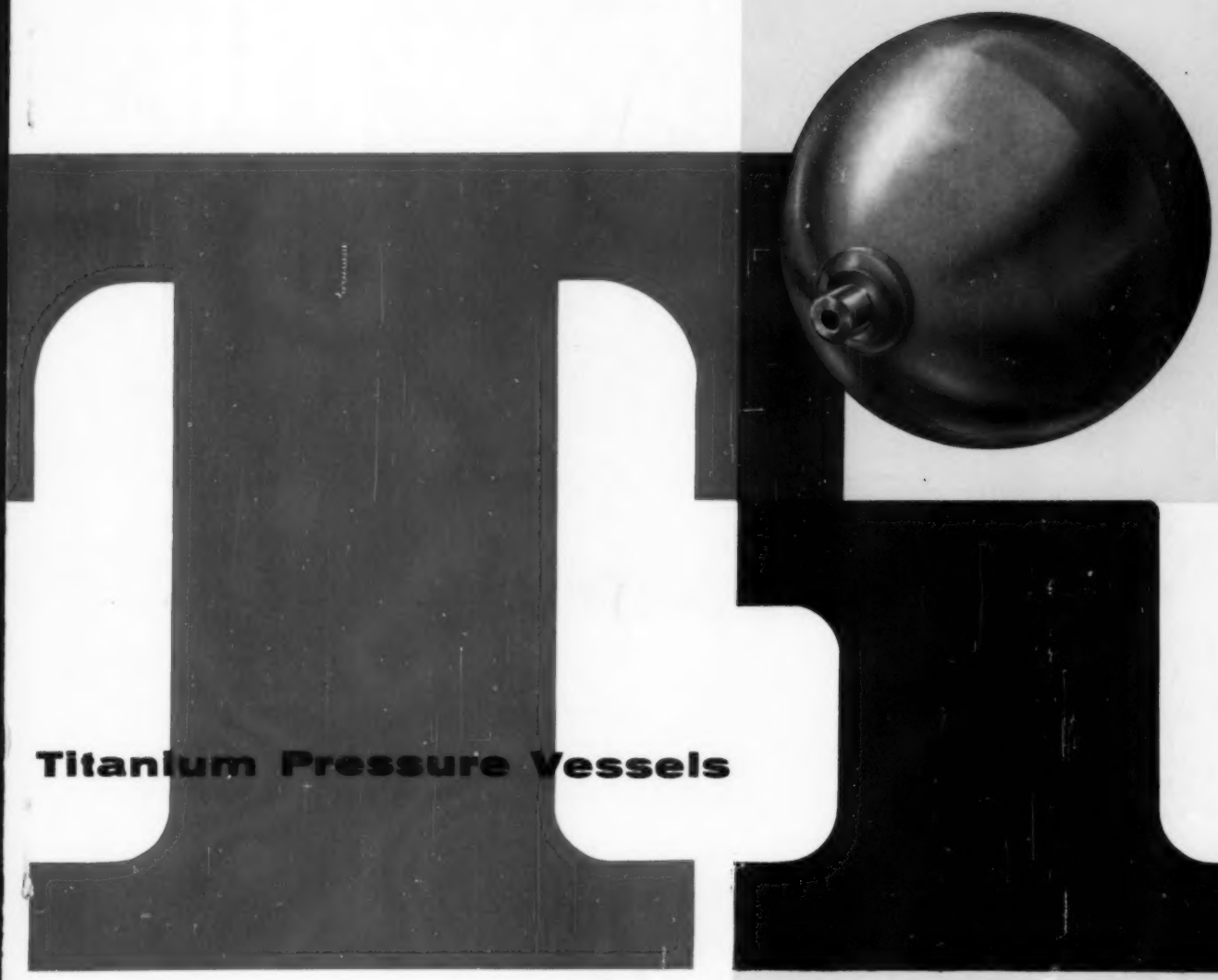
DECEMBER 7, 1961

MACHINE DESIGN

A PENTON PUBLICATION — BIWEEKLY



Titanium Pressure Vessels

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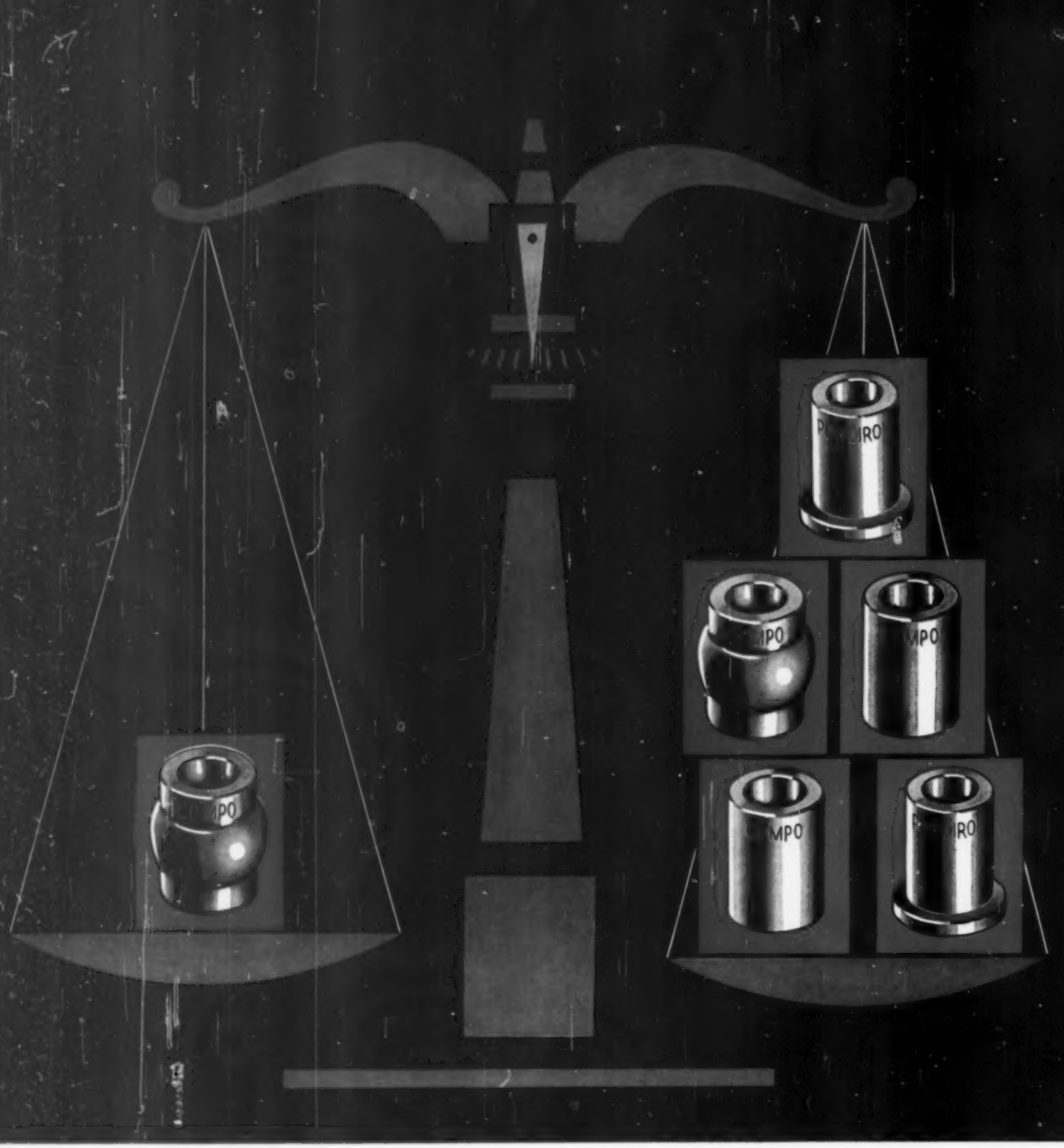
MR. STEVENS RICE
UNIVERSITY MICROFILMS
313 N. FIRST ST.
ANN ARBOR, MICH.

FARNSWORTH



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The world's largest line of air valves is also the most advanced because of the Ross engineering staff

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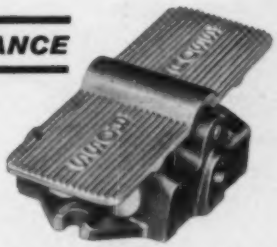

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Time delay sequencing valves

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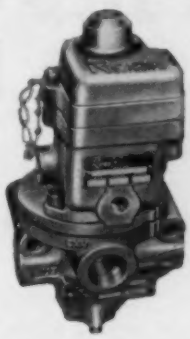

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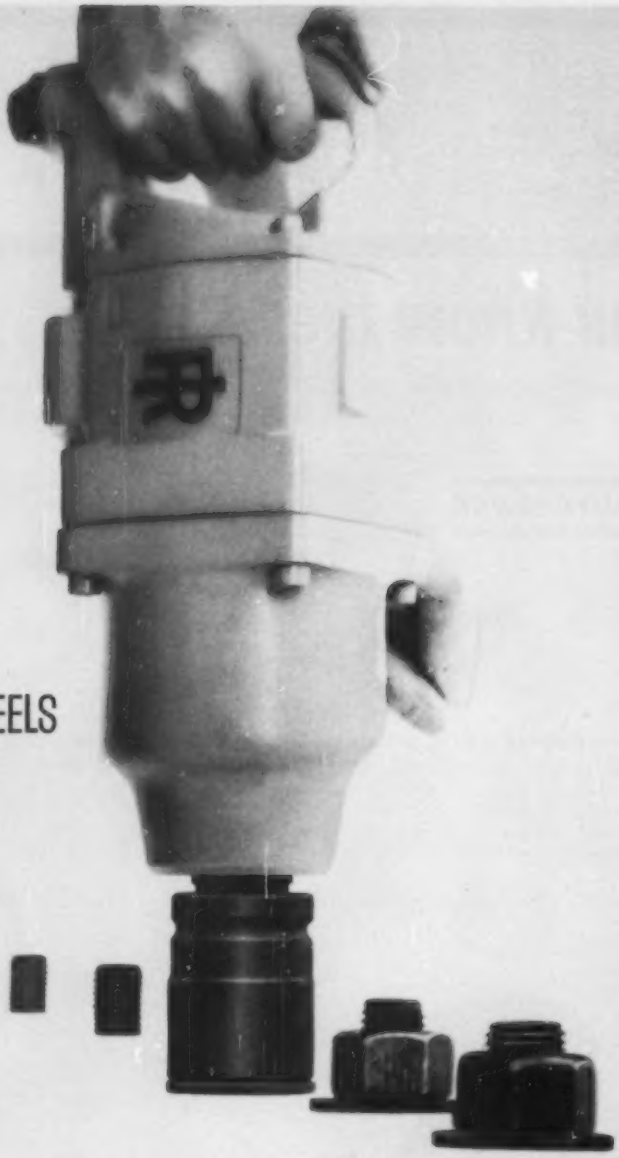

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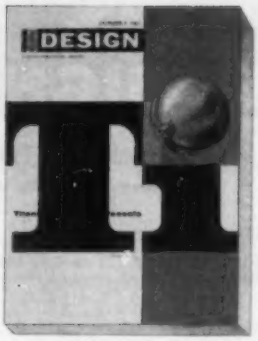

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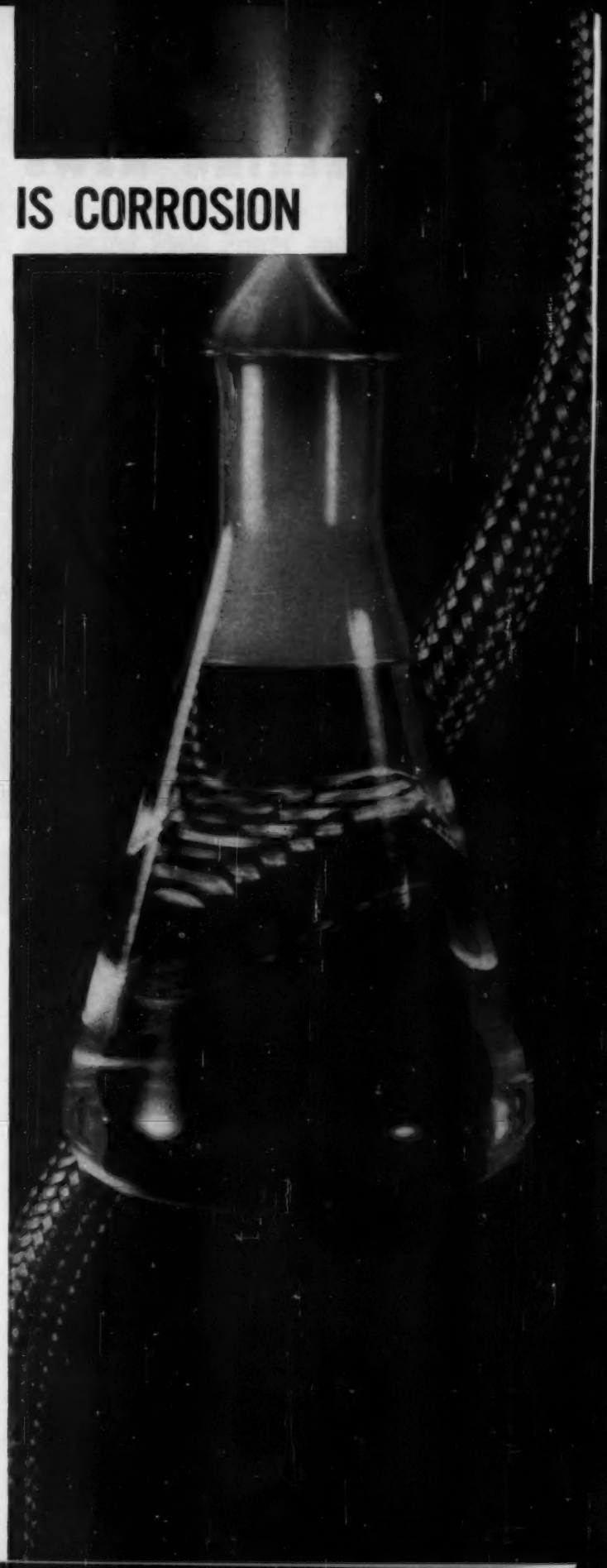
inside/outside

WHEN THE PROBLEM IS CORROSION

count on Anaconda hose of Teflon



If you're faced with the problems of corrosive atmospheres or of conveying corrosives, specify hose of Teflon* by Anaconda. These rugged, resilient connectors are being used to convey chemicals, steam, hot water, fuels, air, gas, liquids, semi-solids, and have proved the ultimate in durability and dependability. They are lightweight, flexible and serviceable at temperatures from −65° F to 450° F.

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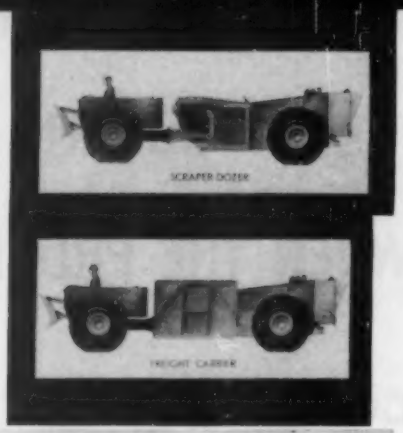
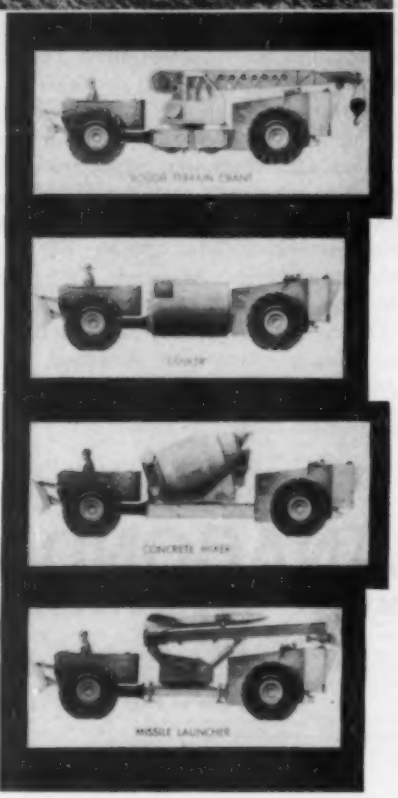
MACHINE DESIGN

ENGINEERING NEWS



Work-Horse Vehicle Swaps Midsections



CHICAGO—The trend toward special-purpose military vehicles suffered a reversal last month when Barnes and Reinecke Inc. announced development of a new multipurpose "work horse" that floats, crawls, climbs, and can be flown into remote locations. Able to handle virtually any construction work, it can travel up to 35 mph.

Called UET-RT (Universal Engineer Tractor—Rubber Tired), the vehicle features a unique sectionalized design that permits attachment of a wide range of interchangeable work units. It can be used to build runways or roads and sweep them clean of snow, mix cement, fight fires, haul cargo, or transport a full squad of Army engineers along with their tools into a combat area. It can also be helicopter lifted in sections.

One UET could replace many different standard military vehicles, according to B&R. In addition to reducing the number of spare parts required for field operations, the vehicle would give Army engineers a new mobility —they would not wait for hard-to-transport equipment. The vehicle has several novel features:

- It can self-load its scraper bowl with 8 cu yd of available soil in 60 sec—doubling its own working weight. Soil can be ejected by the machine when the unit is to be transported.
- Body and bowl unit serve as a hull when the vehicle is floating (unassisted) across inland water.
- Special attachments can be field installed to convert the UET into a machine shop.

Fluid Power news

World's largest injection molding machine OILGEAR equipped

Report No. 12,202 From Oilgear *Application-Engineering* Files

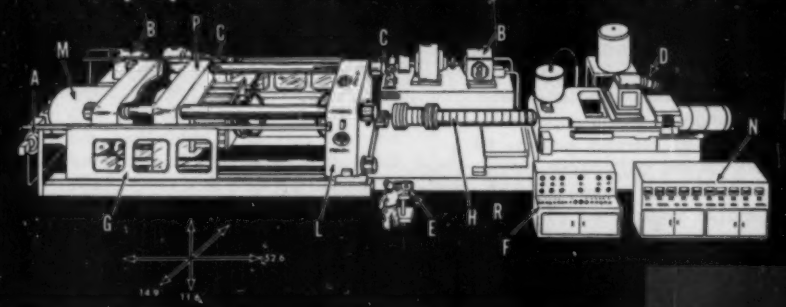
How OILGEAR-MEIKI design teamwork perfected Fluid Power and Control System for the world's largest, in-line, screw-injection, plastics molding machine.

Hitachi, Ltd., Tokyo, Japan — User
Meiki Co., Ltd., Nagoya, Japan — Machine Designer and Builder

PROBLEM: To design and build a hydraulic-powered molding machine for single-shot injection molding of the largest amount of thermoplastic material ever attempted. Provide sufficient mold area to produce large electrical appliance components.

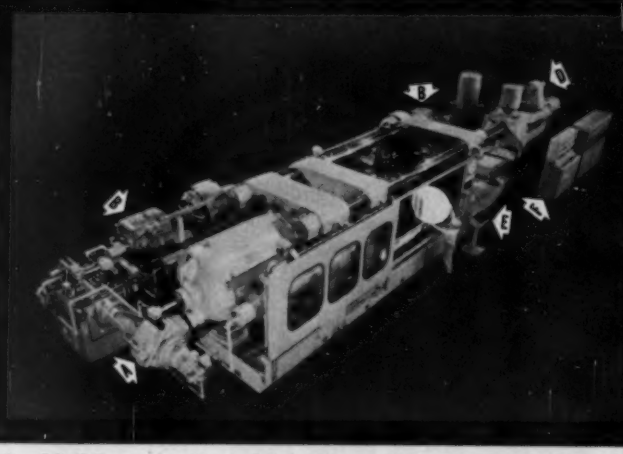
REQUIREMENTS: 1. Direct injection capacity of 1,100 ounces (68 lb) of polystyrene per shot. 2. Accommodate a mold 53 3/16" wide, 82 11/16" high, and a minimum of 55" thick. 3. Straight hydraulic clamping unit with 126" daylight opening, 71" stroke, 2,500 tons force — and remotely controlled adjustable speed up to 485 ipm, with automatically controlled slow-down for smooth closing and opening. 4. Adjustable hydraulic injection speeds up to 285 ipm. 5. Variable speed hydraulic drive on 6" feed screw — from 0 to 38 rpm — with torque up to 20,000 lb ft. 6. Semi-automatic, and manual pushbutton cycle control from a remote console. 7. Precision control of speeds and pressures. 8. Positive interlock, and smooth, shockless operation of all functions. 9. Heavy-duty, durable, efficient hydraulic components for continuous, dependable, high-speed operation.

OILGEAR Application-Engineered Fluid Power and Control Systems for the Meiki SJ-150 "Screw-Ject" Injection Molding Machine. MEIKI



A — Oilgear solenoid pilot operated 12" surge (prefill) valve. **B** — Oilgear heavy-duty, electrohydraulic servo-controlled, two-way, variable delivery pumps. **C** — Oilgear heavy-duty constant delivery pumps. **D** — Oilgear motor. **E** — Remote control console with Oilgear preset units. **F** — Centralized control panel for hydraulic pressure and speed control with Oilgear preset units. **G** — Motor-driven safety doors — both sides. **H** — 10-zone independently controlled heaters. **L** — Deflection-free stationary platen. **M** — 2,500-ton clamping cylinder. **N** — Temperature control panel. **P** — Movable platen. **R** — Rotating device for injection unit.

SOLUTION: Cooperation and teamwork between Meiki engineers specializing in molding equipment — and Oilgear engineers specializing in Fluid Power applications — made the world's largest injection molding machine a huge success. After being demonstrated at the Tokyo World's Fair, the machine is now in production at Hitachi, Ltd. Two of Oilgear's newest heavy-duty electrohydraulic servocontrolled, two-way, variable delivery pumps with automatic pressure unloading devices supply Fluid Power for . . . adjustable, high and low-speed opening and closing of clamping platen . . . driving Oilgear heavy-duty motor on plasticizing and injection screw . . . charging auxiliary accumulator in injection ram system . . . operating injection ram at variable speeds. Small Oilgear heavy-duty constant delivery pumps operating at pressures to 3,300 psi provide positive clamping force, and shift and turn the injection unit. Oilgear solenoid pilot operated surge (prefill) and direction control valves perform auxiliary functions. Through push-buttons and Oilgear preset units on the remote control console, operator can select — rapid advance clamp ram speeds to 485 ipm . . . clamp ram slowdown speeds to 80 ipm . . . injection ram speeds to 92 ipm with one pump — to 184 ipm with both pumps — and up to 285 ipm using the accumulator . . . slow clamp opening speeds to 80 ipm . . . fast clamp opening speeds to 460 ipm. When holding pressure for curing, control automatically reduces pump stroke and power input to a point just sufficient to maintain the required pressure. The Oilgear motor-driven injection screw shaft runs continuously to keep molding material under constant shear or agitation for more uniform heating, melting, bubble-free injection — and lower injection pressures and clamping forces.



On Meiki's entire line of injection molding presses, hot plate presses, forming presses and die casting machines, the "byline" is *Fully Automatic — Fully Hydraulic* with OILGEAR quality Equipment . . . *for the lowest-cost-per-year!*

For practical solutions to YOUR rotary or linear drive and control problems, call the Factory-trained Oilgear Application-Engineer in your vicinity. Or write, stating your specific requirements, directly to . . . . .

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Giant Mirror To Be Ground from Silica

World's largest piece of fused silica—62 in. diam by 11 in. thick—will soon go to work as the primary mirror in a new precision telescope. Fabricated by Corning Glass Works, Corning, N. Y., the giant glass disc is now being precision ground and polished. The telescope, to be constructed at the Naval Observatory, Flagstaff, Ariz., will help determine distances and movements of stars up to 600 trillion miles from the solar system and will enable astronomers to observe deep-space probes and distant satellites. It will increase man's "seeing capacity"—the ability to measure motion and determine position of celestial bodies—by 100 times. Fused silica, one of the purest materials known, will not alter shape when subjected to extreme temperature fluctuations. Because of this near-zero expansion coefficient, it produces distortion-free images when used as a telescope-mirror material.

Poor Planning Spikes Research

COLUMBUS, OHIO — Long-range profits from industrial research more often depend on decisions made before projects are undertaken and after they are completed than on what actually happens in the laboratory, according to Dr. Clyde Williams, president, Clyde Williams and Co. Generally speaking, industrial laboratories do an excellent job in the execution of research projects. Most of the errors of commission and omission lie in decisions as to what projects should be undertaken and what should be done when a project is completed.

"As yet, industrial management has not created adequate procedures for selection of research projects or effective mechanisms for deriving the most value from the research results that are obtained." There is a tendency for a company to select ideas and projects that are variations of the familiar. When a truly novel product concept comes along, it may be voted down in favor of one that is more closely related to the existing line. Too late, it is found that the novel concept has made variations of old-line products obsolete, and that someone else has gotten the new, rapidly expanding business.

Failure to properly use research results after they have been obtained probably subtracts from over-all benefits more than does poor selection of projects, Dr. Williams stated. Management fails to extract maximum profits from research results by indecision and refusal to act promptly. There are now many hundreds of product concepts, already adequately researched and ready for production, sitting on the laboratory shelf, awaiting exploitation. Companies are realizing no returns because they are uncertain of how to proceed.

Topics

An amateur toothbrusher can do a better job with a mechanical brush, according to tests conducted by the University of Kansas Dental School. The teeth of 614 children were 41 per cent cleaner when they used a battery-operated brush than when they brushed in the usual way. Very little difference in effectiveness, however, was observed in another test group—dental students, who presumably have greater skill with manual-type brushes. Test results also showed that tooth-brushing time passed more swiftly with the mechanical brush. One subject brushed for nine minutes and reported that he enjoyed the sensation and didn't get so tired as he usually did.

• • •

For the man who checks everything, there is now a new auto accessory. It provides (for $59.95) a continuous reading on the car's miles-per-gallon performance.

• • •

A fifth wheel has been patented by Jule Brinn, a General Motors Corp. engineer, as an aid to parking. Positioned at right angles to the car's rear wheels, it ordinarily does not touch the road, and its tire is not filled with air. To park in a tight place, the driver first positions the right front wheel near the curb, then turns a valve which inflates the odd tire. Shifting into reverse and stepping on the accelerator turns the wheel and parks the car. GM has no plans for production.

• • •

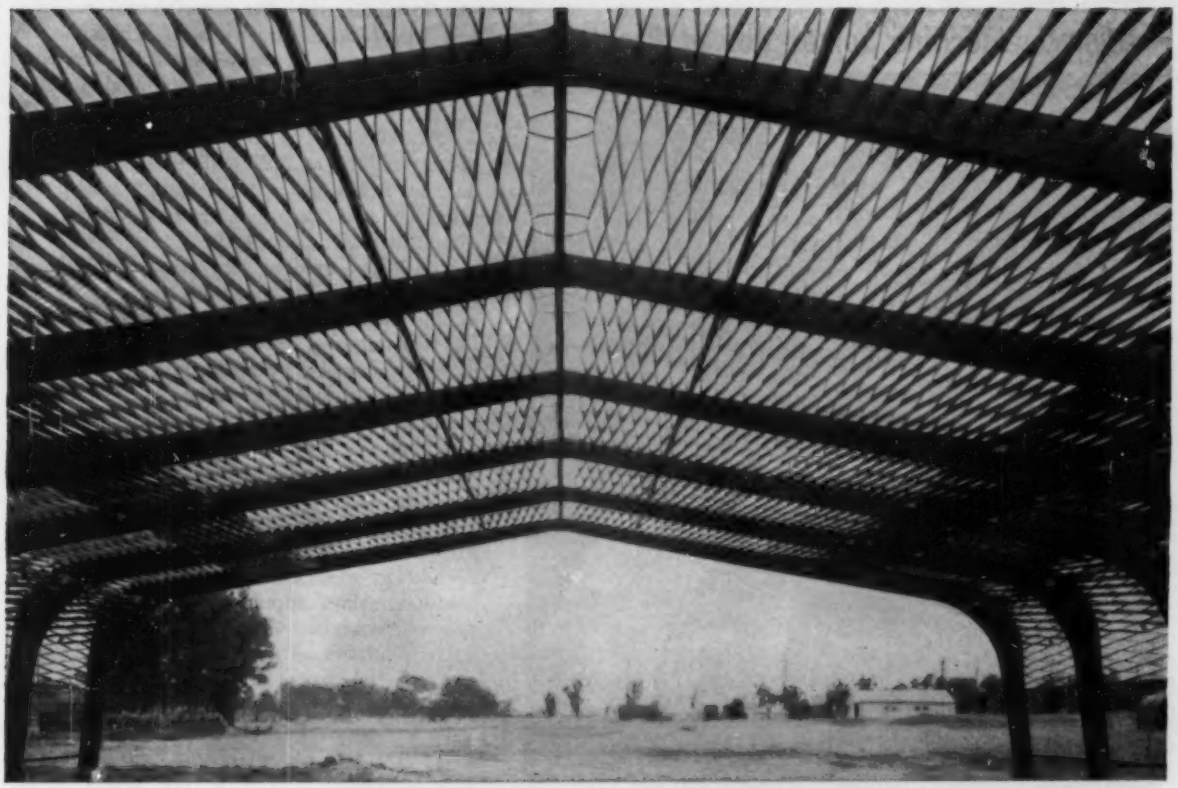
A new intramural sport—mathletics—is being pursued in twelve Westchester County, N. Y. high schools. The county Interscholastic Mathematics League sponsors competition in which students from each of the schools solve identical problems within certain time limits.

• • •

Name-droppers: Promoters of ocean research have coined a new word—hydrospace—to describe their bailiwick.

• • •

Help in hiring is offered new interviewers and persons who only occasionally screen job applicants. The American Management Association has made a 12-in., 33⅓-rpm microgroove record of two typical interviews between job applicants (one an engineer) and an industrial employment manager. The record, "Interviewing the Potential Employee," comes with a training manual and is available from Publication Business, American Management Association, 1515 Broadway, New York 36, N. Y. Cost to AMA members is $10; to nonmembers, $15.



How wood engineering helps improve lightweight roofing performance

NEEDED: a supporting structure for roof covering that could take maximum advantage of modern, lightweight roofing materials. Plastic, plastic-and-fiberglass, pressed fiber products, textiles, plywood, and light metals serve best as roofing only if supported *continuously* by the structure.

To meet this need, Gamble Brothers developed the Gambella — a lamella-type structure which provides, in effect, an expanded purlin (beam) which distributes roof loads uniformly to the framing members. This uniform loading makes possible the use of framing members of smaller dimension for equivalent loads.

Problems like this are "all in a day's work" to the wood engineers at Gamble Brothers—a unique organization designing and building a wider variety of wood products than any other U. S. woodworking company. Today they're working in three principal areas: (1) improvement of present wood products (2) development of new wood products (3) product development in combinations of wood and other materials.

Why not present *your* design problem to Gamble Brothers? WOOD may be the answer!

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This 28-page booklet describes Gamble facilities and services in detail. Includes many photographs of unusual products designed, tested and perfected by Gamble Brothers. Write for your copy today! Gamble Brothers, Inc., 4619 Allmond Ave., Louisville, Ky.

If the problem involves wood, Gamble can help!

GAMBLE BROTHERS, INC.

4619 Allmond Avenue, Louisville, Kentucky

Circle 208 on Page 19

Arithmetic Machine Solves Voiced Problems

Measuring circuit determines whether sounds are "voiced" or "unvoiced." Voiced sounds, "a," "o," "m," and "r," originate in the speaker's larynx; unvoiced sounds are the "f," "s," and "h" type hisses. Shoebox registers words in three parts. First and last are unvoiced, and the middle a voiced sound.

SAN JOSE, CALIF. — An experimental machine now being demonstrated does arithmetic on voice command. Designed by Advanced Systems Development Div., International Business Machines Corp., "Shoebox," recognizes six words and ten digits spoken into a microphone. When "plus," "minus," and "total" are spoken, the tiny device instructs an adding machine to calculate and print-out correct answers to simple arithmetic problems.

Now being used to study the technical feasibility of designing machines to recognize and handle spoken information, Shoebox may be the forerunner of devices that provide answers to questions posed by people who have no time to program computers. Although IBM has no plans to manufacture such machines, the company believes they might be useful to the airplane pilot and the cashier at a supermarket checkout counter, among others.

In operating Shoebox, a person first speaks into a microphone, which converts his voice sounds to electrical impulses. A measuring circuit classifies impulses according to various types of sounds. Circuitry in the solid-state device contains only 31 transistors, fewer than two for each word it recognizes.

This approach provides considerable tolerance to incoming speech. Some numerals or words may be spoken crisply or slurred with little deterioration in recognition ability. Speakers may also sing some words with little sacrifice in accuracy.

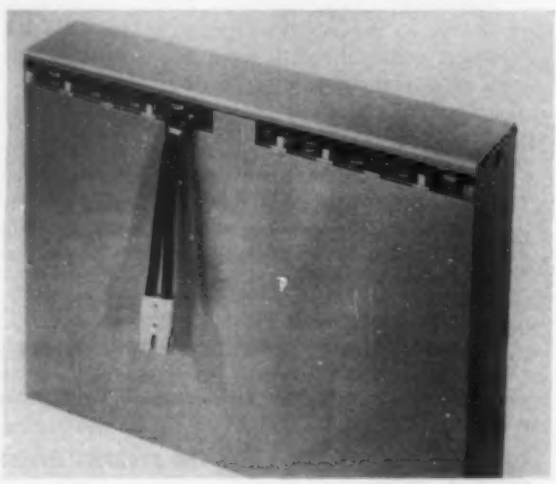
Although the device will respond to a wide range of voices, it works best when adjusted to the vocal characteristics of one speaker.

Redesign Puts More Power in Ni-Fe Batteries

PHILADELPHIA—Electrical capacity of nickel-iron alkaline storage batteries has been increased nearly 77 per cent, reports Exide Industrial Marketing Div., Electric Storage Battery Co. They now produce 1.202 whr per cu in.—up from 0.68—yet conform to dimensions of standard truck-battery compartments.

Accomplished through mechanical design innovations, the power boost gives the nickel-iron units the stamina of lead-acid batteries. They can now be used to power electric industrial trucks in the heaviest-duty material-handling operations, according to the company. The improved capacity was achieved without changing electrochemical balances:

- Perforated nickel-steel tubes that contain the positive active material now are welded together electrically to form a continuous piece from top to bottom of the plate. Previously, rows of parallel tubes, fastened end to end on a grid, spanned the length of the plate.
- Perforated steel strips that contain the negative active material now run the entire length of the negative plate. Previously, the negative material was contained in rows of short rectangular pockets pressed into a grid framework.



Parts eliminated in the redesign include positive and negative separators, side-rod insulators, and wooden trays in which interconnected cells were assembled. These changes made possible increases in capacity of individual cells, number of positive tubes (by 25 per cent per plate), and length of the plates (by one third).

There's a bold, new look at Screw & Bolt. To the industrial designer, this new look means infinite design capability. Thousands of samples of specials we have made attest to our ability to make most any fastener you can design. Screw & Bolt's **Imagineering** is at your disposal, too! ■ Send for our booklet "Imagineering," and when you need threaded fasteners or parts, think of Screw & Bolt!

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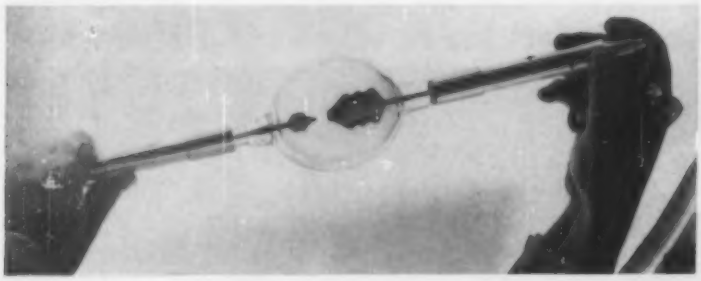


Operating in a high-pressure atmosphere of xenon, GE's new arc lamp produces as much light as 327 sixty-watt household light bulbs. Free from noise, smoke, and fumes, it arcs so brilliantly that engineers who tested the device had to wear welder's helmets (right). The 5000-w lamp, a direct-current source in an ellipsoidal-shaped quartz bulb, has an overall length of slightly more than 19 in.; the bulb itself measures approximately 3.5 in. diam by 4.25 in. long. A 145-amp current flows from cathode to the ¾-lb anode, and the anode temperature gets as high as 6000 F.

Xenon Lamp Outshines the Sun

CLEVELAND—Nearly three times as bright as the sun, a new lamp is the most efficient light producer ever designed. Developed by General Electric Co., Large Lamp Dept., it produces 275,000 lumens at an efficiency of 55 lumens per watt.

First use for the light source will be in a solar simulator for space-vehicle investigations, but company spokesmen predict its high operating stability and freedom from noise, smoke, and fumes will earn it other applications as well.

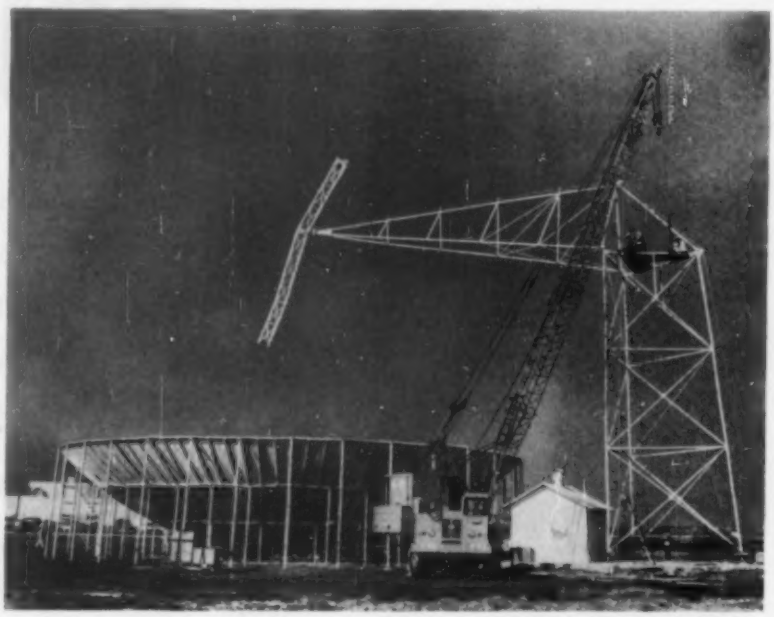
As a solar simulator, it closely approximates solar radiation across the total spectrum—through ultraviolet, visible, and infrared regions. When banks of lamps are aimed at parabolic mirrors, the mirrors reflect a parallel beam of light that is capable of producing the effect of sunlight on space vehicles near the earth. Flux density is 130 w per sq ft.

The xenon-arc system will help determine thermal balance of a spacecraft, and will test the performance of devices designed to respond to solar radiation. These include thermionic and photovoltaic cells, which convert heat and light into electricity for the operation of the vehicle's electronic gear.

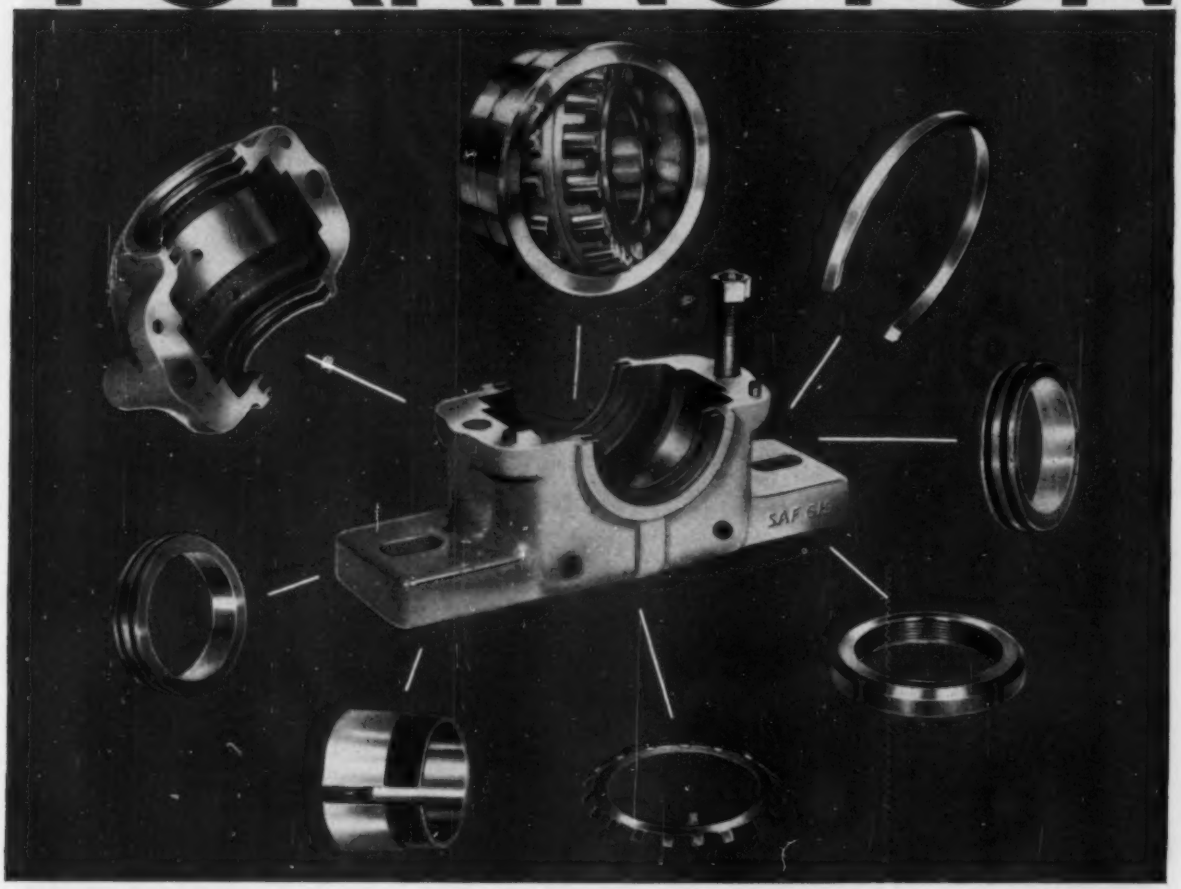
The 5-kw lamp, used in a large searchlight, could throw a beam of one-billion candlepower, sufficient to enable a person to read a newspaper at a distance of about 15 miles. The armed services are expected to find the lamps useful not only in conventional searchlights, but also in infrared detection and signaling devices. Operating over a temperature range up to 20,000 F, the arc is an emitter of near-infrared energy.

Stationary Cosmic Ear

A new radio telescope that is the largest of its kind doesn't have to move to scan the heavens. Erected at Lockheed Missiles and Space Co., Sunnyvale, Calif., the hemispherical antenna looks like a smaller version of the 250-ft dish at Jodrell Bank, England, but there is one major difference: Instead of rotating on its axis to track an object, the telescope focuses on a relatively small steerable collecting antenna that is suspended from a boom directly over the center of the dish. The 85-ft hemisphere sits stationary on the ground. A larger radio telescope of the same type is presently being constructed in Puerto Rico, but it is not scheduled for completion before late next year. According to Lockheed, the telescope is really a small experimental prototype of what will eventually be built—perhaps one as large as 1000 ft in diam.



TORRINGTON

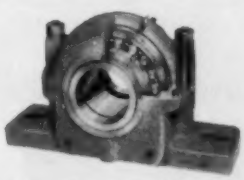


TORRINGTON SPHERICAL ROLLER BEARING PILLOW BLOCKS ...THE INSIDE STORY

All these parts make up a standard series Torrington Spherical Roller Bearing Pillow Block. What you *can't* see in the illustration is the painstaking engineering that goes into each part.

Housing caps and bases, for example, are doweled in pairs throughout manufacture to insure perfect register. The triple labyrinth seals are designed to avoid rubbing contact. A removable stabilizing ring allows "fixed" or "float" operation. The Torrington Self-Aligning Spherical Roller Bearing provides top operating efficiency even under heavy load and misalignment.

Do you have a pillow block problem? It pays to investigate the outstanding performance and long service life of the Torrington Spherical Roller Bearing Pillow Block. Call or write us today.



- ☐ Self-aligning bearing for high radial and thrust capacity
- ☐ Split housing for easy installation and inspection
- ☐ Grease or oil-bath lubrication
- ☐ Standard or heavy duty series available
- ☐ Closed end housing optional
- ☐ "Fixed" or "float" operation

progress through precision

THE TORRINGTON COMPANY

TORRINGTON BEARINGS

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Circle 210 on Page 19

Quartz Resonator Stays Stable at 535 C

NEW YORK—By subjecting quartz to electrolysis, scientists at Bell Telephone Laboratories have discovered the material is suitable as a high-temperature crystal resonator. Quartz crystals could now become useful in piezoelectric devices exposed to extreme environments.

The Bell technique removes sodium and lithium impurities, the major causes of energy absorption at high temperatures. Crystals so treated can be made to resonate very stably at up to 535 C if cut at higher orientation angles than previously thought practical.

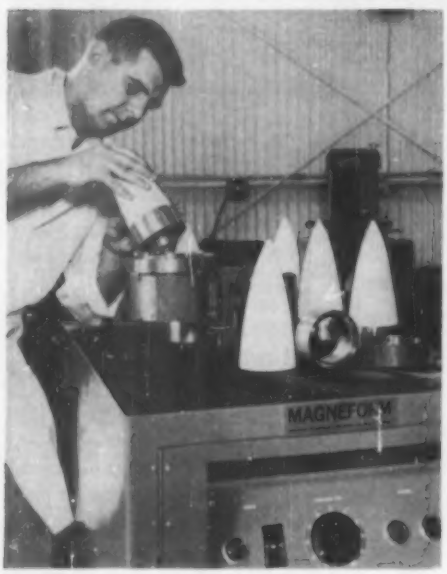
Frequency at which a quartz crystal resonates depends greatly upon its temperature, but every crystal can be tailored to an optimum operating temperature. When at the optimum, slight temperature changes will not cause a large frequency deviation. In general, as the cutting angle is increased the optimum temperature goes up.

After being electrolyzed in a furnace, quartz crystals are cut into wafers that can be used as frequency control resonators at high temperatures.

Previously, it had been generally agreed that all optimum temperatures occurred below 250 C, regardless of cut angle. At higher temperatures, quartz crystals absorbed so much vibration energy that precise experiments were impossible.

Recently, Bell's Dr. J. C. King found that once the impurities were eliminated, he could measure optimum temperatures well above 250 C in properly cut crystals. The discovery makes possible fabrication of treated quartz resonators for use near heat engines, in missiles, and in other applications where it would be difficult or costly to maintain moderate temperatures.

Electromagnetic Forming Goes to Market



Metal bands are tightly attached to ceramic missile nose cones by electromagnetic force squeezing them into beveled edges.

SAN DIEGO, CALIF.—First electromagnetic metal-forming machine available off the shelf assembles, attaches, and shapes metals quickly without ever touching the work piece. Developed by General Atomic Div., General Dynamics Corp., the new tool, called Magneform, pulses a powerful magnetic field against the work, creating pressures greater than 50,000 psi. The field pulses last for 10 to 20 millionths of a second.

Easily interchangeable coils make the machine highly versatile. By changing coils, the operator can accomplish a variety of successive operations—swaging, expanding, forming, shearing, dimpling, blanking, embossing, etc. Pressure, applied uniformly to complex contours, wraps the metal into indentations and over protrusions. The brevity and uniformity of the pulse assure there will be no damage to the work piece.

With the current model, operations can be repeated every six seconds, including recharging the capacitor. The machines are adaptable to remote control and automated operation for quantity production at a faster rate.

Magneform grew out of experience gained by General Atomic in its controlled-fusion research program. The extreme temperatures required to "ignite" a fusion reaction—4 x 10^8 F or higher—would instantly vaporize a container made of any known material. Therefore, "magnetic bottles," whose walls are formed by magnetic fields, were designed to surround and contain intensely hot gases.

Ft-Sq Thermoelectric Source Generates Three-House Power

NEW YORK — A new thermoelectric material generates more electricity from high-temperature heat than the best previously known materials, according to scientists at Radio Corp. of America. Laboratory tests indicate that a generator using plates of the new material (1 sq ft surface area) heated to about 1800 F produces 10 kw of electricity —nearly three times the amount consumed at any given time in the average home.

The material, an alloy of germanium and silicon, is called a major discovery that broadens the pattern of efficient thermoelectric power for general application. According to RCA, it opens the way to a full range of compact and self-contained generators that can utilize:

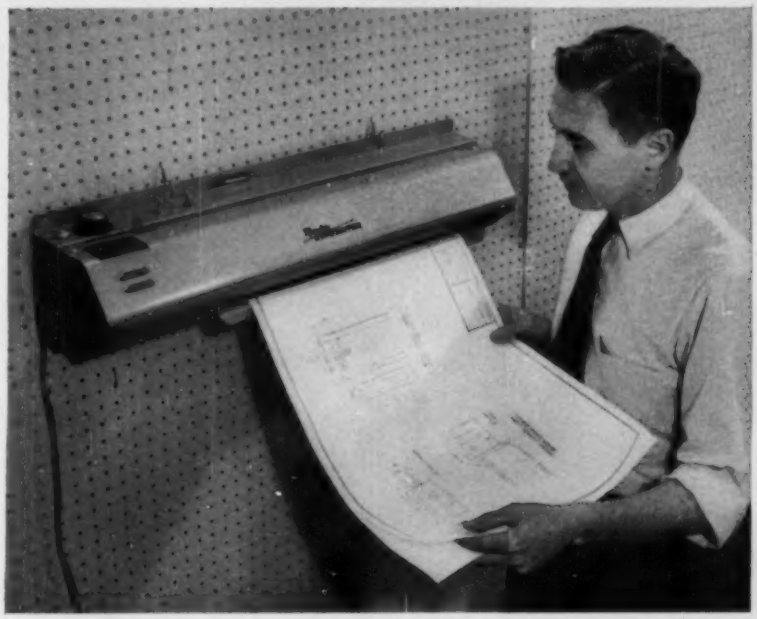
- High-temperature nuclear heat sources to power equipment in space.
- Solar energy to furnish electricity in desert or tropic regions.
- Flame sources to power essential equipment in homes, summer camps, and even air raid shelters.

"We can now begin to think of ultimate use of silent thermoelectric generators to power outboard motors and other machinery in everyday use," according to Dr. James Hillier, RCA vice president.

In addition to its high temperature and power characteristics, the alloy is reported to offer advantages of high efficiency and long life. Use of the material in combination with lower-temperature thermoelectric materials developed earlier now clears the way to silent heat-operated power packages that have efficiencies rivaling those of gasoline engines and other conventional generators for military, space, commercial, and domestic uses, according to the company.

"RCA's thermoelectric power research program," says Dr. Hillier, "already has produced materials that operate with 10 to 12 per cent efficiency from lower-temperature heat sources—a substantial gain over the general 6-9 per cent range reported elsewhere for such materials. The new alloy operates several hundred degrees hotter and already exceeds 9 per cent."

DRAFTING TRENDS



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Quick checkprints for larger manufacturers. Even huge engineering divisions with their own reproduction departments praise Expeediter's practical, on-the-spot convenience for quick copies of preliminary sketches, checkprints, conference data, visual presentations. Hundreds of companies have placed Rotolites in their engineering and drafting rooms for "self-service" whiteprints in a hurry.

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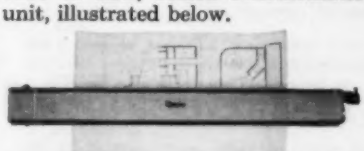

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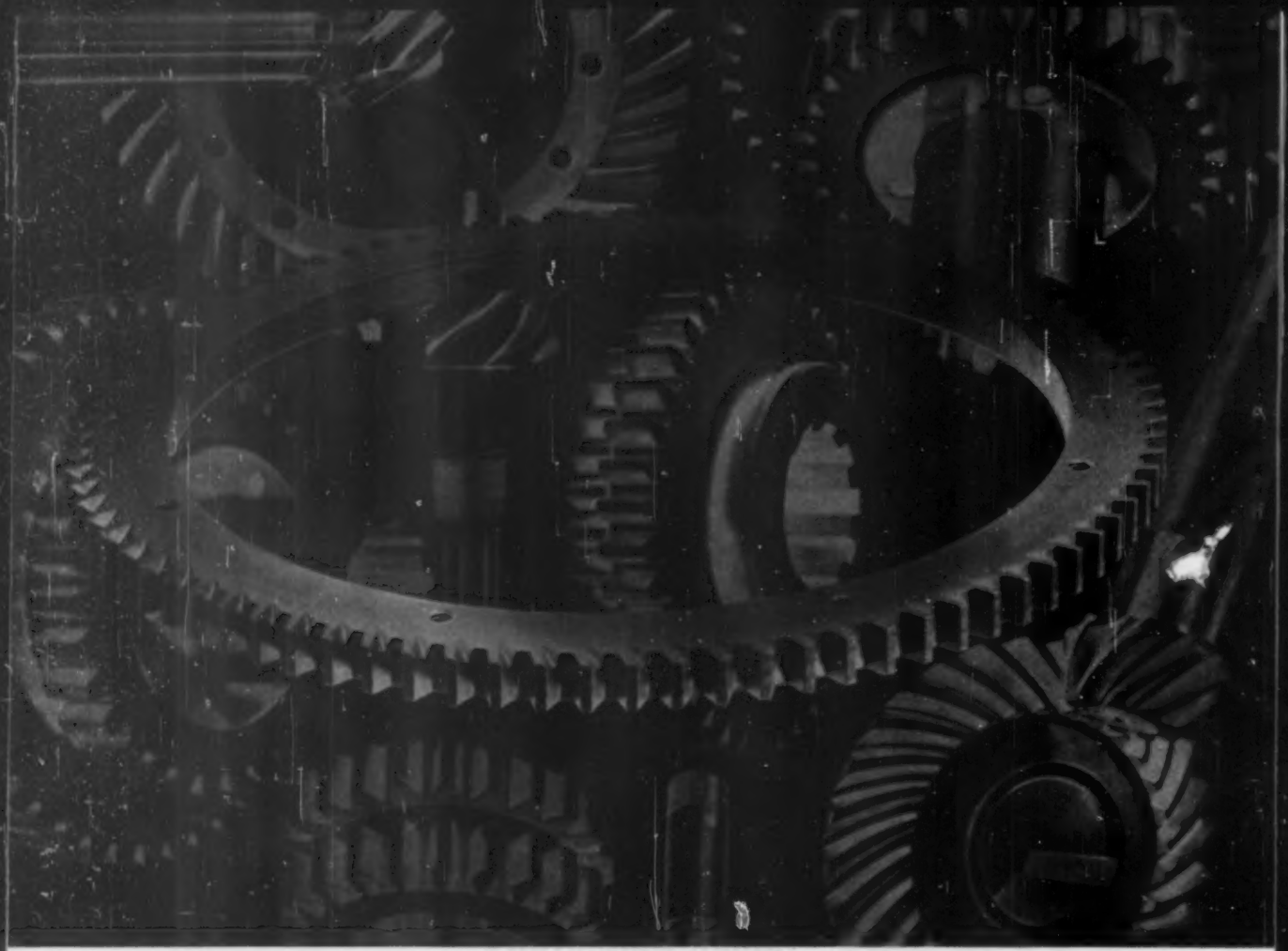

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Descriptions of items start on Page 218. Starred items are from Nov. 23 issue.

Electric, Electronic

503 **Monoplanar Switching.** 8 pp. Ucinite Co., Div., United-Carr Fastener Corp.

505 **Electromechanical Components.** 140 pp. Siamco Div., Tech-Ohm Electronics Inc.

507 **Bimetal Thermometers.** 16 pp. Weston Instruments Div., Daystrom Inc.

513 **Industrial Engine.** 4 pp. Wisconsin Motor Corp.

520 **Polarized Relays.** 6 pp. Magnetic Devices Inc.

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531 **Silicon Rectifiers.** 44 pp. Rectifier-Capacitor Div., Fansteel Metallurgical Corp.

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537 **Slip-Ring Assemblies.** 16 pp. Superior Carbon Products Inc.

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545 **Flush Pushbuttons.** 8 pp. Westinghouse Electric Corp.

548 **Polarizing Systems.** 4 pp. Ucinite Co., Div., United-Carr Fastener Corp.

604 **Meter Relays.*** Discusses locking-contact units and their components. Bulletin 5, 24 pp. Assembly Products Inc.

605 **Precision Resistors.*** Provides data on Cal-R wirewound power resistors. 16 pp. California Resistor Corp.

606 **Tachometer Systems.*** Complete systems, including generators, indicators, drives. 12 pp. Herman H. Sticht Co. Inc.

607 **Power Metal-Film Resistors.*** Specifications for Type PMF units. Bulletin P-9, 2 pp. International Resistance Co.

608 **Snap-Action Switches.*** Complete data on line of basic units. 20 pp. Cherry Electrical Products Corp.

609 **DC Solenoids.*** Descriptions, characteristic and pull curves. Bulletin 605, 4 pp. Synchro-Start Products Inc.

610 **Electric Motors.*** Describes 25 ac and dc units in sizes from 0.001 to 7.5 hp. 26 pp. Elcor Div., Indiana General Corp.

611 **Gear Motors.*** Covers unidirectional and reversible units. Catalog 1061, 6 pp. Electro Counter & Motor Co.

612 **Power Foot Switches.*** For industrial and commercial applications. Catalog 62, 8 pp. Linemaster Switch Corp.

613 **Circuit Breaker.*** Type 550 hydraulic-magnetic unit. Bulletin 29-550, 4 pp. Standard Control Div., Westinghouse Electric Corp.

Hydraulic, Pneumatic

502 **Control Valves.** 8 pp. Conoflow Corp.

506 **Pressure Hose.** 6 pp. Atlantic Metal Hose Co. Inc.

511 **Fluid Coupling.** 18 pp. Hydraulics Inc.

515 **Machined Bellows.** 4 pp. Hydrodyne Corp.

528 **Metallic Gaskets.** 28 pp. Packing & Friction Materials Div., Johns-Manville Co.

529 **Hand Pumps.** 8 pp. Commercial Shearing & Stamping Co.

532 **Plastic-Clad Pipe.** 8 pp. Polymer Corp.

534 **High-Pressure Flowmeter.** 2 pp. Rotron Controls Div., Rotron Mfg. Co. Inc.

538 **Water Pump.** 4 pp. Tuthill Pump Co.

549 **Pressure Indicators.** 8 pp. Pall Corp.

614 **Industrial Gas Data.*** Physical, chemical properties, conversion tables, capacity data on gas delivery and storage systems. Form ADE-890, 48 pages. Air Reduction Sales Co., Div., Air Reduction Co. Inc.

615 **Air Cylinder.*** Squair Head units with 1½ through 14-in. bores. Bulletin SQ-61, 48 pp. Tomkins-Johnson Co.

616 **Vane Pumps.*** Series TIC pumps for pressures to 2500 psi. Bulletin 200-A, 8 pp. Denison Engineering Div., American Brake Shoe Co.

617 **Hydronic Valves.*** Units for hydraulic heating and cooling systems. Bulletin HYD-1, 12 pp. Cash-Acme.

618 **Hydraulic Filter.*** Tell-Tale filter for suction-line use in hydraulic systems. Vickers Inc., Div., Sperry Rand Corp.

619 **Hydraulic Equipment.*** Covers hand and foot-operated Hi-Low units. Bulletin 160, 8 pp. Star Hydraulics Inc.

620 **Blowers and Pumps.*** Types RAS and RGS blowers and gas pumps. Bulletin RAS-261, 8 pp. Roots-Connersville Blower Div., Dresser Industries Inc.

Mechanical Equipment

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518 **Bearing Data Sheet.** 2 pp. Barden Corp.

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626 **Friction Materials.*** Technical data, specifications on industrial materials. Catalog FM-57A, 24 pp. Packing & Friction Materials Div., Johns-Manville Corp.

627 **Laminated Plastics.*** Covers 25 common grades, plus 6 grades of vulcanized fiber. Form SW 62, 8 pp. Taylor Fibre Co.

628 **Nonferrous Casting Alloys.*** Covers 40 alloys most frequently specified for centrifugal castings. Bulletin 100, 4 pp. Wisconsin Centrifugal Foundry.

629 **Reinforced Plastic Parts.*** Design possibilities for molding parts with integral electric heaters. Form 101, 4 pp. Bischoff Chemical Corp.

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631 **Recorders.*** Direct and servo-operated switchboard and portable units. Bulletin GEA-6933A, 12 pp. General Electric Co.

632 **Precision Test Instruments.*** Integrated sound, vibration, and data-analysis instrumentation. Catalog ES-10, 24 pp. B & K Instruments Inc.

633 **Self-Contained Recorder.*** Impact-O-Graph mechanical, impact, acceleration, gravity recorder. 4 pp. Impact-O-Graph Corp.

Electrical, Electronic

532 Motor-clutch assembly has 1/20-hp, 1500-rpm motor. Precision Specialties Inc.

536 Microminiature potentiometer for panel applications has ½-in. diam. Miniature Electronic Components Corp.

539 DC timing motor eliminates cogging action. A. W. Haydon Co.

563 DC accelerometer is small unit for industrial applications. Giannini Controls Corp.

567 Stepping motor takes "add" and "subtract" pulses. U. S. Science Corp.

571 Rotary potentiometer has standard linearity of 0.3 to 3.0 per cent. Potentiometer Div., Daystrom Inc.

575 Glow lamps have glass length of ½ in. and bulb diam of 0.244 in. Miniature Lamp Dept., General Electric Co.

577 Subminiature switch for precision, low-resistance uses. U. S. Switch Corp.

580 RF transistors for fm and am radios. Semiconductor & Special Purpose Tube Div., Amperex Electronic Corp.

581 Servo motor has output of 0.013 hp at 7500 rpm. Eicor Div., Indiana General Corp.

583 Circuit breaker is temperature-sensitive, miniature unit. Sylvania Electric Products Inc., subsidiary, General Telephone & Electronics Corp.

585 Switch lights are fail-safe units which use T-1 ¾ lamps. Pandar Inc.

586 Silicon-controlled rectifiers are subminiature units. Solid State Products Inc.

589 Latch relays mount in place of two center unit poles. Ward Leonard Electric Co.

592 Printed-circuit connector has 210 terminals. Viking Industries Inc.

593 Precision thermostat resists vibration, shock, and salt spray. Thermel Inc.

595 Predetermining counter has pushbutton reset. Presin Co. Inc.

596 Indicator switch has built-in readout with 12-display capacity. Industrial Electronic Engineers Inc.

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550 Flow-control valve for 5000-psi oil or air-pressure systems. Auto-Ponents Inc.

558 Ball valves for pressures to 1000 psig. Hills-McCanna Co.

561 Hydraulic cylinder has spring-locked packing. Ward Hydronics Inc.

564 Insulating gaskets for ASA flanges. Parker Seal Co.

566 Flow-control valves in new superhard alloy. Flow Systems Inc.

569 Float-valve assemblies operate horizontally and vertically in small space. Robert Mfg. Co.

573 Plastic piping for low-pressure use. Carl N. Beetle Plastics Corp.

576 Hydraulic pumps in many variations and types. Romec Industrial Div., Lear Inc.

579 Rotary actuator for use with valves, dampers, and other flow-control devices. Electra Motors Inc.

582 Glass-fiber tubing has low dimensional change under high humidity. National Vulcanized Fibre Co.

584 Remote position indicator consists of sensor and remote indicator. Jordan Controls Inc.

588 RFI gasket for use between complex mating surfaces. Technical Wire Products Inc.

591 Solenoid valve has cushioning action and controlled flow. Allied Control Co.

597 Wire-braid hose for pressures to 1000 psi. Goodyear Tire & Rubber Co.

Mechanical Equipment

553 Idlers, tensioner shafts in antifriction types. Brewer Machine & Gear Co.

555 Adjustable-speed drives incorporate new helical steel gears. Zero-Max Co.

562 Belt drive saves space and cuts noise. Manhattan Rubber Div., Raybestos-Manhattan Inc.

568 Heavy-duty clutch engages smoothly at low speed ranges. Comet Industries.

572 Roller bearings are sealed, cage-type units. McGill Mfg. Co. Inc.

578 Conveyor belt eliminates ply separation. B. F. Goodrich Industrial Products Co., B. F. Goodrich Co.

594 Air-bearing spindles have rotational accuracy of one-millionth of an inch. Professional Instruments Co.

Assembly Components

551 Nylon zipper for industrial use is strong and lightweight. Slide Fastener Div., Waldes Kohinoor Inc.

554 Waterless decals have one or two-side imprints. Allied Decals Inc.

557 External wrenching bolt is 180,000-psi unit which meets new military specification. Standard Pressed Steel Co.

565 Antifriction screw is nonrecirculating-type unit. R.C.S. Tool Co.

Materials

560 Thermoplastic resin is medium-impact type. Marbon Chemical Div., Borg-Warner Corp.

570 Antifriction tape is nontoxic, noncontaminating. Permacel.

574 Mylar polyester film has dielectric strength of 25 kv ac. E. I. du Pont de Nemours & Co.

587 Glass-epoxy laminate meets all military and NEMA specifications. Taylor Fibre Co.

590 Silicone paste for use in temperatures from −75 to over +400 F. Silicone Products Dept., General Electric Co.

Engineering Dept. Equipment

598 Pressure transducers are thin, flexible units with size of 1 x 1 in. Spitz Laboratories Inc.

599 Dual-gun oscilloscope has two amplifiers with 100 mv to 100 v sensitivity. Packard Bell Electronics.

600 Strain gage for operation to 180 F. Metric Inc.

601 Vibration analyzer is fully transistorized. Raydata Corp.

602 Pocket comparator is enclosed in battery-operated illuminator. Edmund Scientific Co.

603 Recycling timer maintains time intervals from 0.05 to 5 sec. Hufco Industries.

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EDITORIAL ARTICLES

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25-1 **Fallout Meters.** Present availability to the average citizen—with the hope that they never are needed. (3 pp.)

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22-4 **Compression-Spring Design.*** Design methods, procedures, materials, allowable-stress data. (11 pp.)

22-7 **Keeping Bolted Joints Tight.*** Avoiding decoupling of vibrating joints held together by threaded fasteners. (4 pp.)

21-5 **Servovalves for Force Control.*** Using servovalves for accurate control of force in hydraulic system. (6 pp.)

21-10 **Critical Speed of Shafts.*** Nomogram for quickly finding critical speed of shafts. (3 pp.)

20-3 **Gasket Loads.*** Four techniques for evaluating flange pressure factors to improve flanged-joint design. (7 pp.)

20-9 **Pin-Joint Design.*** Nomograph design procedure for matching joint proportions to operating requirements. (4 pp.)

19-3 **Statistical Dimensioning Program.*** Setting up a program to improve the way assemblies function, while allowing all possible dimensional tolerance. (6 pp.)

19-11 **Quadratics-Cubics-Quartics.*** Three methods, based on nomograms, to get quick, direct answers; procedures for refining roots to any degree of accuracy. (8 pp.)

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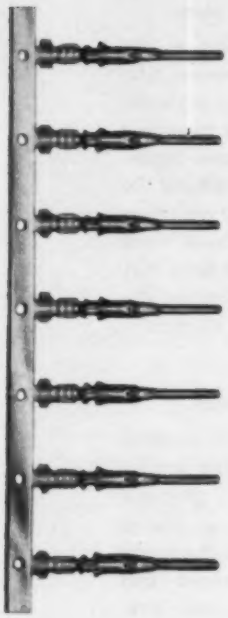

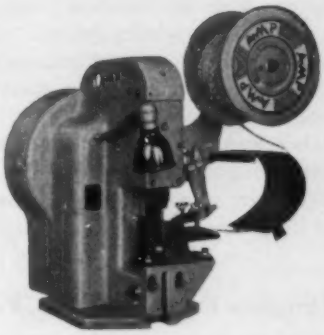

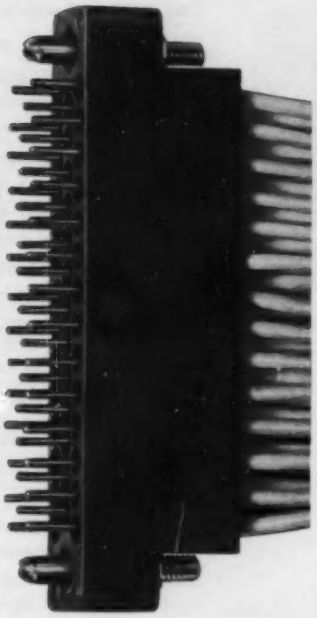

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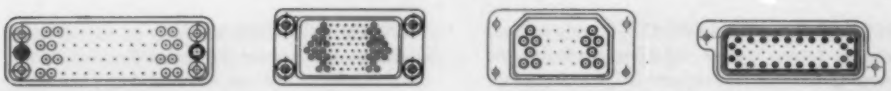

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Circle 213 on Page 19

trends

engineering/personal

Engineers Shouldn't Be Administrators, Says Administrator

"The professional man's inability to communicate intelligibly in the businessman's language makes it imperative to have a spokesman who can supply interpretations free from the technical jargon and gibberish that the engineer—often intentionally—hides behind." This quotation illustrates the point that, since engineers and managers have fundamentally different personalities, an engineering manager should be specifically trained to bridge the gap between the two. The quotation is from *Engineering Management and Administration*, a new book written by Val Cronstedt and published by McGraw-Hill Book Co. It covers management structures; responsibilities of administrators, development engineers, and designers; plus a number of other subjects.

Emphasis on Theory Threatens Experimentalists, Products

Because of a growing dependence upon mathematics and theoretical methods to solve complex engineering problems, relatively few science graduates enter the experimental field. Dr. Max M. Frocht, professor of mechanics and director of experimental stress analysis at Illinois Institute of Technology, pointed this fact out to attendees of the recent International Symposium on Photoelasticity. He also stressed that modern design—stressing requirements of speed, weight, and temperature—presents problems that cannot be solved by theoretical methods alone. Overestimation of the power of analytical methods in stress analysis, he said, could result in inferior products. Dr. Frocht advocates an integration of theoretical and experimental methods to produce well-rounded engineers.

PHILOSOPHICAL, SPECULATIVE thinking should not be discouraged by our professional societies, says Arthur B. Bronwell, president of Worcester Polytechnic Institute. He recently pointed out to the Engineers Council for Professional Development that there is much "hole-plugging" research—piercing out of voids in existing knowledge. But, he suggests, talented young people could derive untold future benefits from the great minds of the present. Inordinate delays, he says, always occur in the embryo stages of new ideas; it is here that "philosophical discussions could illuminate the future."

MATHEMATICIANS DOUBLED in number between 1954 and 1960. A survey by the Bureau of Labor Statistics also shows that the median age of those surveyed was a comparatively young 32.5; 94 per cent had college degrees, including 26 per cent with master's degrees and 7 per cent with Ph.Ds. Over-all median salary was $8500; for those with B.S. degrees working in private industry it was $7300; for master's and doctor's degree holders, it was $10,000 and $13,000. More than half of the survey respondents work in basic or applied research and development in the natural sciences and engineering.

electronics

RELIABILITY AND LOW COST are combined in this frozen-in-glass capacitor made by the Corning Electronic Components Div. New sealing techniques and automatic machinery make possible a price that is as much as 60 per cent below that of previous fusion-sealed glass capacitors. Corning also produces fixed-glass dielectric capacitors with 99.9994 per cent reliability over 1000 operating hours for the Air Force's Minuteman missile.

PRINTED CIRCUITS are here to stay, it was agreed at the Annual Technical Symposium of the Institute of Printed Circuits, but parts will be more difficult to make with finer lines, closer tolerances, and more rigid specifications. Discussing recent developments in microsystem electronics, one expert said a primary problem in introducing the new idea is the shortage of design engineers trained to think in terms of using microelectronic systems.

aero/space

X-15 Beats Design Goal

Design stretch remaining in the X-15 research aircraft will probably lead NASA to raise flight-envelope limits to Mach 7 and 500,000 ft. (Original goals: Mach 6; 250,000 ft.) On Nov. 9, the hypersonic vehicle—piloted by Maj. Robert M. White, USAF—exceeded its design speed with a 4093-mph (Mach 6.04) flight. Flown to 217,000 ft on Oct. 11, it will shortly attempt to climb beyond the original 250,000-ft design altitude. During the record speed run (unofficial), leading edges on the X-15 wings reached 1147 F. The rocket engine, delivering 57,000 lb thrust, burned at full throttle for 86 sec.

FLIGHT-RATING TESTS just completed for the first U. S. liquid-hydrogen rocket engine mark a significant milestone in space-vehicle propulsion, says NASA. Performance of the RL-10—developed by Pratt and Whitney—was 30 per cent better than for current hydrocarbon (kerosene) fueled engines. During 20 captive firings under simulated space conditions, the hydrogen engine consistently produced its rated 15,000-lb thrust.

THE INFLATABLE SPACE VEHICLE—a development that led to the Echo satellite series—has earned NASA's William J. O'Sullivan a $5000 award. Proposing the idea for the IGY in 1956, O'Sullivan demonstrated that a thin, aluminum-coated plastic sphere, if inflated beyond its elastic limit, would retain its shape even if internal pressure were lost. The award was recommended by the NASA Inventions and Contributions Board.

computers

Down-to-Earth Solar Cells for Compact Computers

Solar cells—energized by artificial light rather than the sun—supply power for reading punched cards in Burroughs' new B200 computer series. A row of lamps is located opposite a row of solar cells in the computer's card-reading unit; when a punched card is fed between the two rows, light passing through its holes generates electrical voltage and current. Use of the cells aids in compact design.

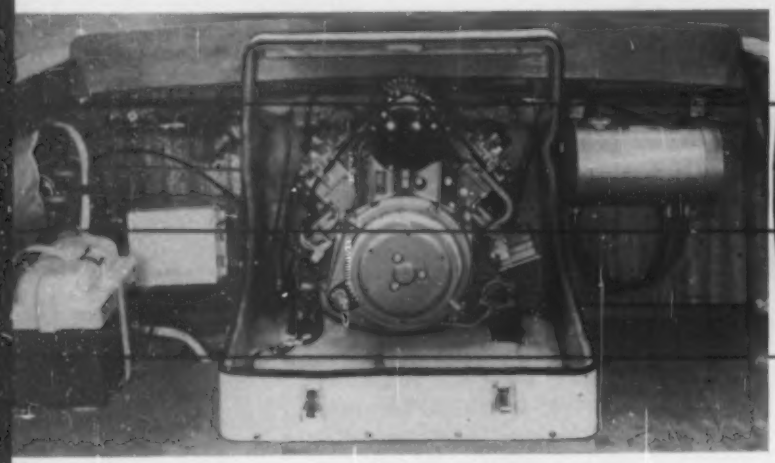
Father of Invention?

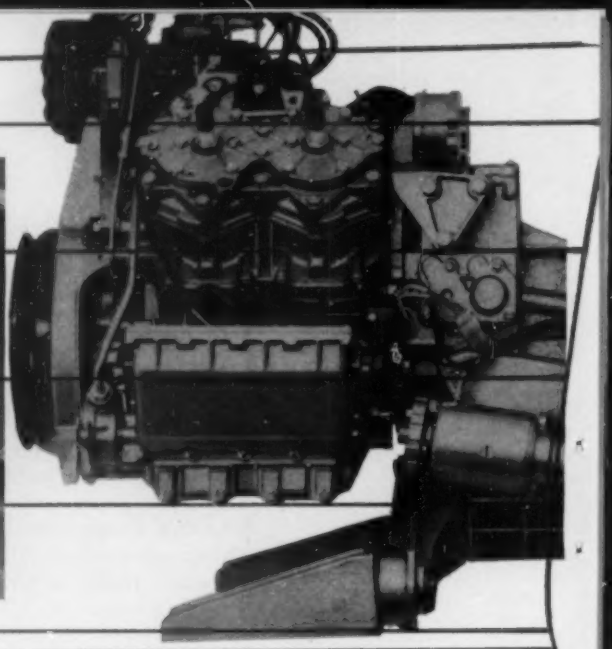
Computers have been hailed as the coming heroes in development of new products and services by Walter W. Finke, president of Minneapolis-Honeywell's Electronic Data Processing Div. He called their speed in problem-solving an "unprecedented stimulant to invention" and predicted that the business that avoids "computer automation" will risk its future.

materials

LOWEST COST SYNTHETIC RUBBER may be a new type copolymer now being evaluated by Acushnet Process Co., New Bedford, Mass. It is an ethylene-propylene rubber, introduced in Italy. DuPont and Enjay Chemical Co. are about to begin production of similar materials in this country. Polypropylene rubber, made from the least expensive and most readily available petroleum products, offers high resistance to chemicals and ozone.

MAGNESIUM HAS GRADUATED from the "wonder" metal stage and has taken its place in the line-up of recognized engineering materials. Producers and users of magnesium alloys were shown more than 150 nondefense products at the recent annual meeting of the Magnesium Association and were told that over 70 per cent of production for structural uses appears in industrial and consumer products. A promising process for magnesium is chemical milling.





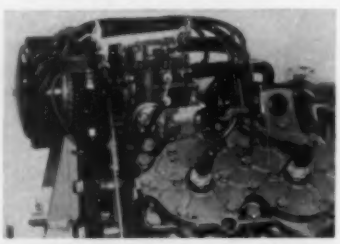
Fail-Safe Metering Supplants Oil-Fuel Premixing in a

Two-Stroke Stern Drive

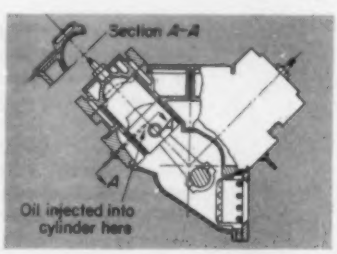
AMATEUR mariners — especially those weak in dockside arithmetic—can forget all about oil-fuel proportions when they service a new two-stroke powerplant built by Outboard Marine Corp. The 80-hp sterndrive unit needs no pre-mixing of oil and gasoline. Instead, engine lubricating oil—held in a tank separate from the fuel supply—is injected automatically into the cylinder bores by a precision metering pump.

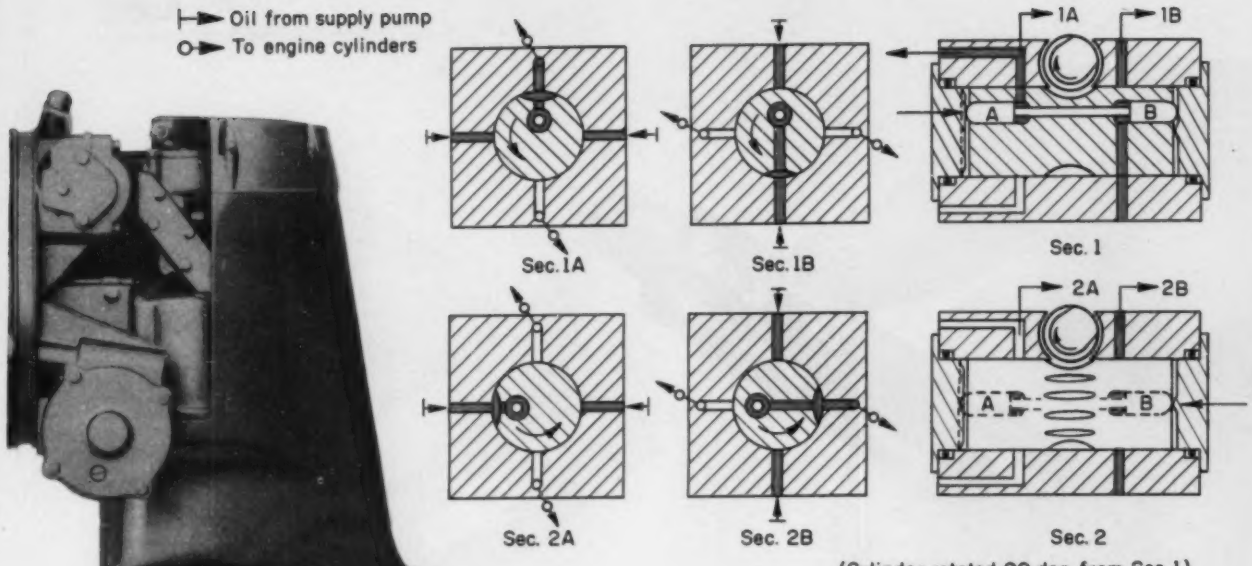
OMC designed a four-way system to protect the engine from accidental or negligent loss of oil supply. The oil tank—when topped off at the same time the fuel tank is filled — is large enough to ensure that gasoline will be gone before the oil is exhausted. To protect the forgetful boatman (and his engine), a red warning light signals a low (1-hr remaining) oil supply. For the completely oblivious operator, a float switch shorts out engine ignition just before the oil is entirely exhausted. Final line of defense is a pressure switch which also stops the engine if the oil supply should fail.

OMC lays no claims for the over-all novelty of metered lubrication for two-stroke gasoline engines. Thirty-odd years ago, it says, two-strokers were lubricated by leading oil directly to the connecting-rod bearing. Thrown around by the rod, oil eventually reached main bearings, cylinder walls, and wrist pin. These rudimentary and inconsistent systems —usually incorporating inadequate low-oil safeguards—frequently over-oiled or under-oiled the engine. Normal consequences were fouled plugs and excessive carbon, or burned-out bearings and scored pistons. At this state of the art, the concept of premixed oil and gasoline—a "breakthrough" for the two-stroke en-



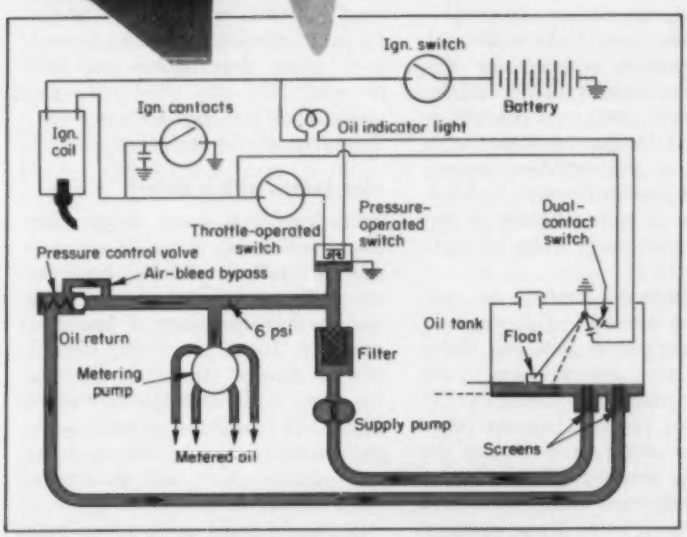
Pressure-lubrication package (above), consisting of metering and supply pumps, mounts on rear face of ignition distributor bracket. Supply pump holds 6 psi pressure on metering-pump at all engine speeds. Metered oil is injected directly into each cylinder bore (sketch, below).





(Cylinder rotated 90 deg from Sec. 1)

Worm-driven barrel in the OMC metering pump encloses a shuttle operating axially between two fixed cam lobes. Oriented 90 deg out of phase, cams translate the shuttle (two pistons and a push rod) to provide four oil-discharge strokes for each revolution of the piston barrel. Discharge ports—connected to the four engine cylinders by extruded nylon tubing—are uncovered in sequence by the piston barrel rotating at a 1:20 ratio with engine speed. Relatively large-volume discharge of the pump is significant, according to OMC, in that it controls the effect of manufacturing tolerances on metering rate. Design aim was to hold rate to ±10 per cent for all pumps, regardless of oil temperature or viscosity.



Oil-tank float switch completes circuit to warning light when oil drops to 1-hr level. If oil is exhausted by continued engine operation, second set of float-switch contacts shorts out engine ignition. Pressure switch constitutes a second engine protection system. During engine start (low oil pressure), pressure switch operates red warning light, also shorts ignition if throttle is advanced beyond "Start" position. When supply-pump oil pressure builds up to normal (6 psi) after a start, pressure switch opens ground circuit for light and ignition.

gine—was accepted as an easy way to increase reliability. Because the early-day engine was on the small side (as was its integral fuel tank) the mixing operation wasn't considered particularly inconvenient.

Today's pleasure-boat operators, however, are leaning toward larger powerplants and longer-range tanks—usually built into the boat. This makes fuel-oil mixing a considerable dockside project. The designers point to another factor that favored OMC's renewed search for a reliable separate oiling system: Large-engine designers are now using ball, roller, and needle bearings (rather than friction types) on crankshafts and rod ends. The piston, then, becomes the moving part that determines the leanest allowable oil mixture. Obviously, pinpointed lubrication, supplied by controlled injection, opens the door to improvements in oil economy.

Designed with the hope they'll stay on the basement shelf:

Fallout Meters

Chirping and flashing, the Personal Radiation Monitor warns industrial researchers of gamma radiation. As the danger level grows, the instrument becomes more excited and the time interval between chirps decreases; at high levels, continuous tones and steady beams of light are produced. The device is manufactured by Elgin Laboratories for Nuclear Materials and Equipment Corp., Apollo, Pa. Intended for use around reactor installations, hot-cell facilities, etc., it was not designed as a fallout-shelter instrument.

SURVIVORS of a nuclear war—snug, perhaps, in their fallout shelters—may still be out of luck unless they can measure the radiation dangers around them. Several citizens' meters, designed for the nonspecialist, are available. Which type is best? Although the Office of Civil and Defense Mobilization is looking into the problem, recommending some instruments and not others, the situation is likely to become more confused before it clears up.

Three kinds of atomic "rain" will pollute the atmosphere during the early fallout period: Beta and alpha particles, and gamma rays. Beta particles (electrons), emitted by most fission products, cannot penetrate very deeply into matter. At worst, they produce skin ulcers and are not dangerous unless taken into the body with food. Alpha particles (helium nuclei), carrying twice the charge, are even easier to stop and are less dangerous externally.

Gamma rays, produced as materials radioactively decay, have a penetrating power similar to x-rays, but are even more energetic. Dangerous outside the body as well as within, they constitute the immediate threat involved in fallout. Citizens' radiation meters must be designed to effectively monitor gamma rays rather than alpha and beta particles, and this rules out most versions of the best-known radiation meter of all—the geiger counter.

Why Bother with a Meter?

Nuclear tests have shown that many radioactive materials are present in fallout debris; however, about 70 per cent of the emerging isotopes have half-lives of less than one day. Radiation levels, starting out at deadly intensities, decrease by about a third in the first seven hours and by another third in seven days. The remaining isotopes decay very slowly—some will be around for a million years.

Survivors holed up in a well-built shelter could expect to take about 100 roentgens on the first day. They could afford this much radiation because, on succeeding days, the accumulated dose would increase very slowly. However, everyone in the shelter might suffer slight radiation

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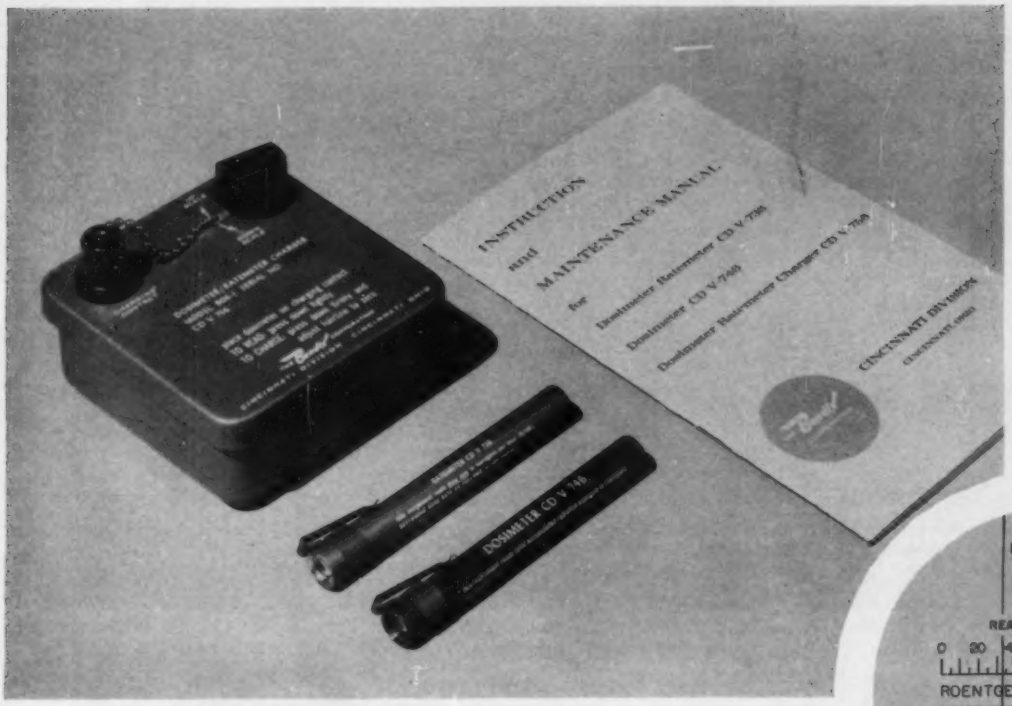
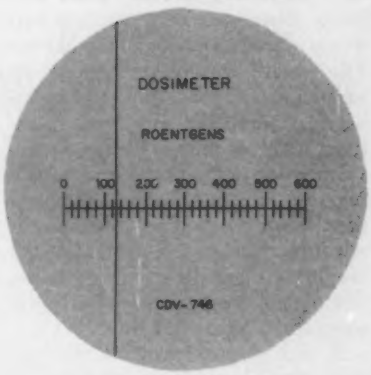


for the Millions



sickness. If the survivors had no meter, they would have no assurance that their dose rate was sufficiently low. Feeling sick and seeing each other sick, they might panic and desert the shelter to hunt for a safer place.

All must stay inside for at least a few days, even if it means going hungry. On the third day, an adult equipped with a meter might be able to leave the shelter for a short time to sweep off the roof or obtain emergency food supplies. He would be taking a risk, but without the meter he might be committing suicide.

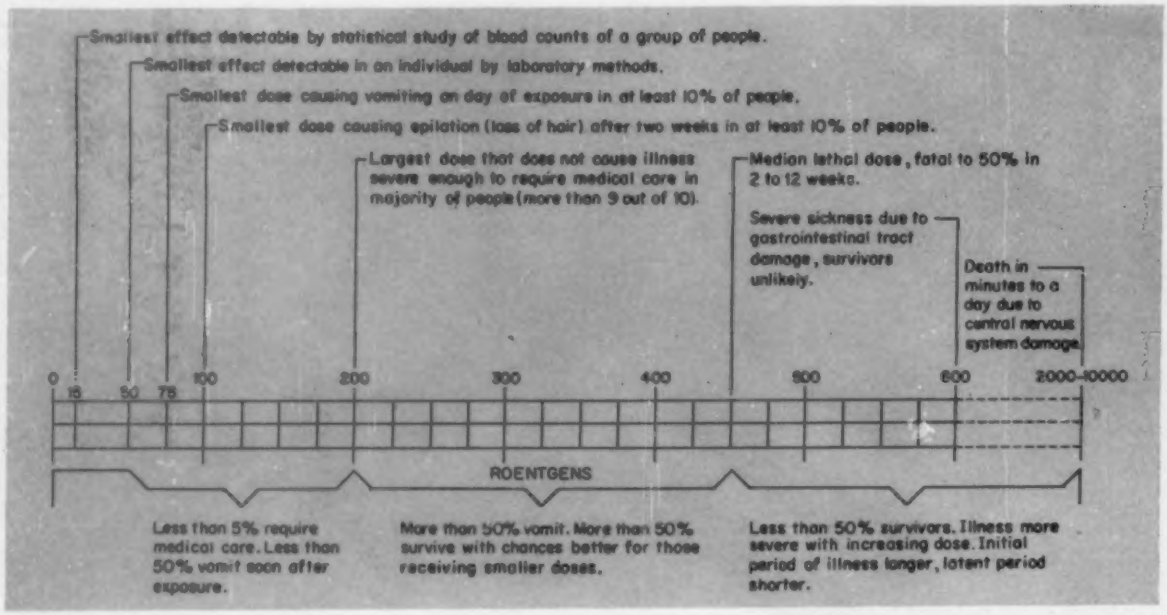
Dilemma for Citizens

Many radiation meters are available, but few are recommended by OCDM—in some cases because the agency has not yet developed testing specifications. Most of the instruments assigned to military and civil-defense personnel are too complicated, not rugged enough, or require too much maintenance for home use. All of the meters originally designed for radiation measurements in industrial laboratories require too much theoretical background for citizens' use, according to OCDM.

"Fountain-pen" dosimeters of the quartz-fiber type are presently the only instruments officially recommended by OCDM. Manufactured by Bendix Corp., Cincinnati Div., and Landsverk Electromer Co., Glendale, Calif., these meters have a short quartz fiber attached to a rigid metal wire that serves as one electrode. They operate on the electroscope principle: When the fiber and wire are charged relative to the other electrode, the two repel each other. When gamma rays barrage the instrument, ions are formed which bleed off the charge, decreasing the mutual repulsion and gradually returning the fiber to its original position. Location of the fiber is a direct measurement of radiation absorbed.

Direct-reading rate meters are presently being studied by OCDM. One of these, an instrument designed by Victoreen Instrument Co., Cleveland, has tested out well and seems likely to be officially recommended once specifications can be

Two dosimeters included in the Bendix kit measure accumulated dose and rate of receiving radiation. The total-dose meter is read periodically, needs no adjustment after being initially charged to zero. The rate meter is zeroed before use, exposed for a measured 1 minute and read. If the dose rate is low, it is then exposed for 10 minutes and read again. Two scales are included on the rate meter, one for each exposure time.


Smallest effect detectable by statistical study of blood counts of a group of people.
Smallest effect detectable in an individual by laboratory methods.
Smallest dose causing vomiting on day of exposure in at least 10% of people.
Smallest dose causing epilation (loss of hair) after two weeks in at least 10% of people.
Largest dose that does not cause illness severe enough to require medical care in majority of people (more than 9 out of 10).
Median lethal dose, fatal to 50% in 2 to 12 weeks.
Severe sickness due to gastrointestinal tract damage, survivors unlikely.
Death in minutes to a day due to central nervous system damage.
0
15
50
75
100
200
300
400
500
600
2000-10000
ROENTGENS
Less than 5% require medical care. Less than 50% vomit soon after exposure.
More than 50% vomit. More than 50% survive with chances better for those receiving smaller doses.
Less than 50% survivors. Illness more severe with increasing dose. Initial period of illness longer, latent period shorter.

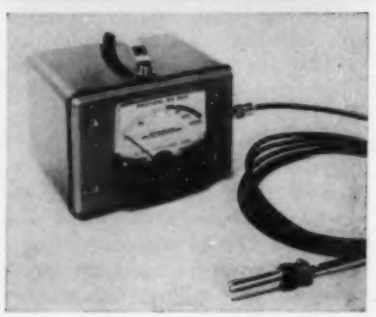
drawn up. According to the manufacturer, the meter will have a short stay on the market. Already a less expensive version with fewer scale selections is nearly ready for production.

Like the Victoreen instrument, most direct-reading rate meters now being offered to the public are battery-powered ionization chambers: The small currents produced by gamma radiation entering the chamber are amplified and read directly on a galvanometer. Originally developed for the military, direct-reading rate meters are more expensive than dosimeters, but they have the advantage of giving instantaneous readings. They do not measure accumulated dose, so they can never supplant dosimeters entirely.

A second generation of rate meters is also becoming available. Said to convert a fallout shelter into a command center, the newer meters come equipped with several probes that can be located outside the shelter to give remote readings. Their advantage is that they allow the homeowner to string a detector to the kitchen. This will tell him when he can safely forage for additional food supplies. Another detector in the basement will tell him when it is safe to move out of the shelter. Disadvantage is that a meter with two probes costs almost twice as much as a standard meter; a three-probe unit costs three times as much.

Civilian version of an instrument developed for the military, the Victoreen meter now being tested by OCDM is the first direct-reading rate meter priced to compete with dosimeters. Lightweight and portable, the device uses fully transistorized circuits for long life. According to company spokesmen, it can sit on a basement shelf for years without needing any more maintenance than that required to check its batteries.

Remote-reading rate meters, manufactured by Lionel Electronics Laboratories Inc., Brooklyn, N. Y. (middle), and Atomic Safeguards Corp., Atlanta, Ga., tie in to one or more detectors outside the fallout shelter. The remote detectors, contained in waterproof housings, are designed to withstand all the hazards encountered by devices left exposed to the weather. Both meters convert into portable instruments when the cables leading out of the shelter are disconnected and either a short probe is plugged in (ASC version) or the instrument is switched to read an internal detector.



CLIMAX MOLYBDENUM

Molysulfide® News Digest

CLIMAX MOLYBDENUM COMPANY, a division of American Metal Climax, Inc., 1270 Avenue of the Americas, New York 20, N.Y.

EDITORIAL PAGES OF LEADING TRADE MAGAZINES FEATURE MoS_2 INFORMATION

Higher temperatures, lower temperatures, greater pressures, longer lubrication life, all have combined to focus more attention on the uncommon lubricating values of molybdenum disulphide.

That's why editors are devoting more and more space to descriptions of what MoS_2 can and cannot do.

One article tells how MoS_2 prevents harmful friction in brake linings. Another discusses its use as a compressor lube substitute. Still another reports on tests of epoxy-resin compositions containing high concentrations of MoS_2 for industrial use on bearings, seals and friction strips.

Press fittings, wire drawing, cutting tools, ball joints—there are MoS_2 stories about these uses, too.

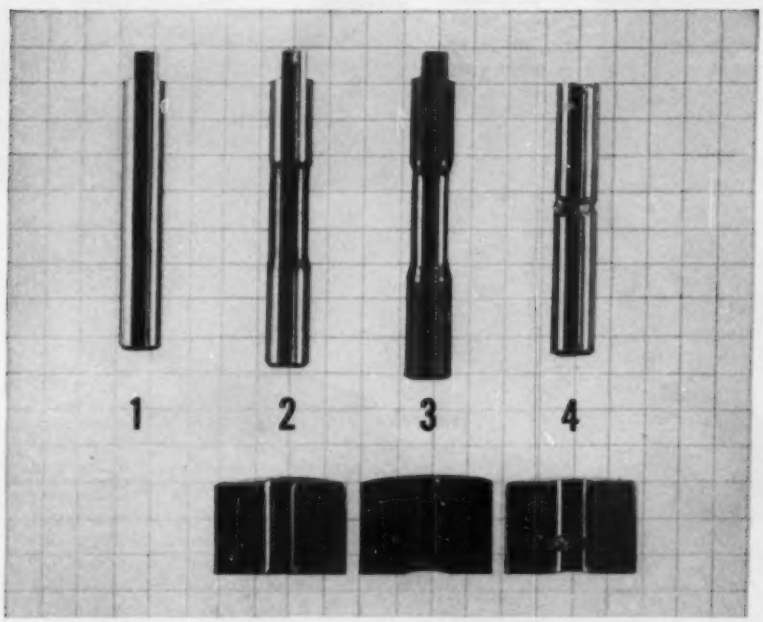
MoS_2 as a solid-film dry lubricant has been the subject of several articles. One details high-temperature properties; another describes a new bearing design that can increase bearing life as much as 450%.

Write us for a complete bibliography of published material on molybdenum disulphide.

P.S. Climax publishes a newsletter that describes even more uses. Let us know if you'd like your name on the mailing list.

Circle 214 on Page 19

Proof of MoS_2's High-Pressure Properties



Photograph above shows mild steel test pins. No. 1: Unused pin, No. 2 (lubricated with mineral oil and Molysulfide) and No. 3 (with Molysulfide bonded coating) were subjected to rotating pressures between bearing halves. Both were elongated and extruded without galling, seizing, or weight loss. No. 4 shows typical failure with conventional lubricant. Note that the key sheared off and pin and block were galled and seized.

Circle 215 on Page 19

ASME SHOW DEVOTES SESSION TO "MOLY" LUBES

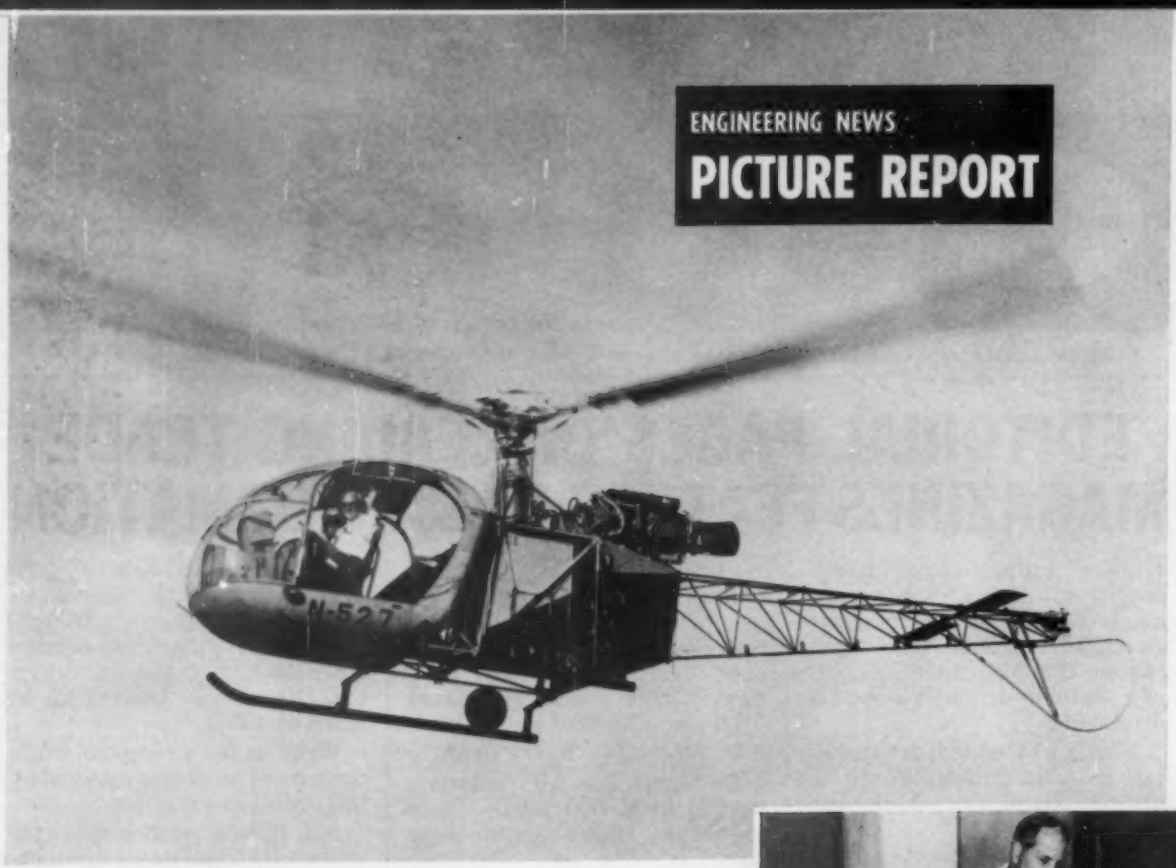
New evidence of mounting interest in molybdenum disulphide was shown recently among members of the American Society of Mechanical Engineers. A spokesman for the Climax Chemical Division was invited to speak on "Molybdenum Disulphide as a Lubricant" before the Machine Design Division at the 1961 Design Engineering Conference. A copy of this 24-page paper is available on request.

At the same meeting, engineers from Socony Mobil Oil Company spoke on "Molybdenum Disulphide as an Additive to Improve the Performance of an Automotive Multi-purpose Grease." Write to Climax for a copy of this paper.

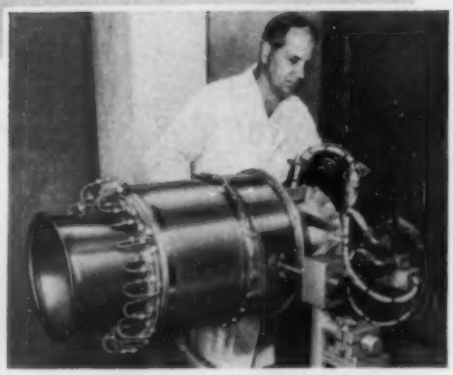
Circle 216 on Page 19

ENGINEERING NEWS

PICTURE REPORT

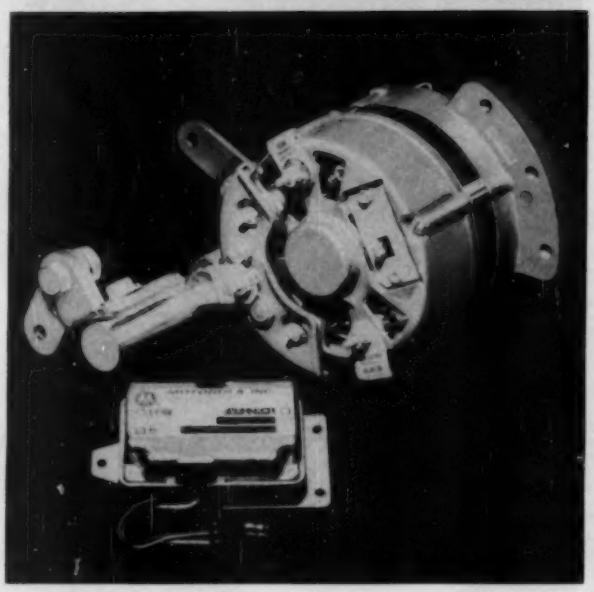


A gas-turbine engine, tailored to the requirements of helicopters by AiResearch Mfg. Div. of the Garrett Corp., powers the Lark. The craft recently completed flight tests, including hovering and climbing to over 10,000 ft. Republic Aviation Corp. will produce the Lark, which is the American counterpart to the French Alouette. The AiResearch model 331 engine, however, offers lower weight, more power, and improved fuel consumption. It is also very quiet—the Lark's test pilot said it was the first helicopter he had ever flown in which he could carry on a normal conversation when the doors were off.



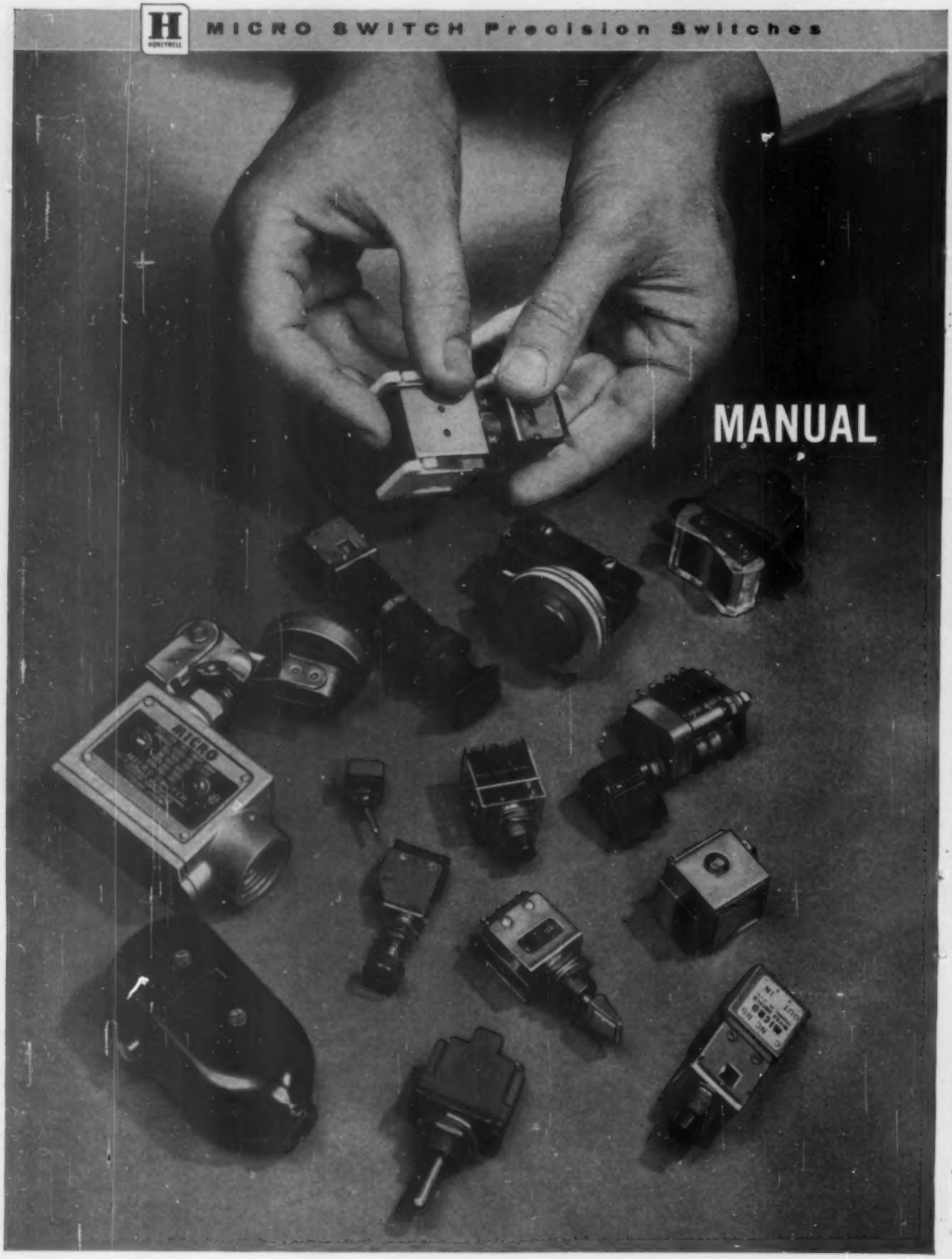
Triservice VTOL will be built by a three-company team of Ling-Temco-Vought, Ryan Aeronautical Co., and Hiller Aircraft Corp. To be used for transporting Army, Navy, and Air Force personnel, equipment, and supplies to unprepared landing areas, the craft will cruise at 250 to 300 knots with an 8000-lb payload. Its operational radius is to be 200 to 300 nautical miles. The plane will be 58 ft long; its cargo compartment, 30 by 7 by 7½ ft. Power will come from four General Electric T64 turboprop engines, driving four conventional propellers and a tail rotor.

The cafeteria patron cooks her own meal on the Mark IV Radarange, just introduced by Raytheon Co. All the diner does is select a precooked frozen meal, put it into the oven, and push a color-coded button which automatically times the cooking. For most meals, only a minute or less is required. The Mark IV, at $1295, costs half as much as previous microwave ranges.



An electronic alternator system, offered by Motorola Inc. as replacement equipment for automobiles, is available as either a 30 or 45-amp unit and will fit most 12-v, negative-ground models built since 1959. Replacing the dc generator and its regulator, the system consists of an alternator, a voltage regulator, and a universal installation kit. Motorola says its system extends battery life from 25 to 50 per cent, even in taxicabs, or passenger cars having a number of power accessories.

Armor is afoot for the U. S. Marines. This "mine" boot, now being tested, has a 6-in. beveled stainless steel sole with a contour wedge to deflect fragments. It was developed by the Naval Medical Field Research Laboratory, Camp Lejeune, N. C., on the basis of medical records which indicate that feet and lower limbs are the most common casualties of land mines. It is expected that such boots will be issued in 1962. Prototypes were made by International Latex Corp., Dover, Del.


MICRO SWITCH Precision Switches
MANUAL

SWITCHES...DESIGNED TO MEET HUMAN-FACTORS ENGINEERING STANDARDS

Adjustable actuator arm. Oil-tight enclosure.

Heavy-duty palm button switch.

Explosion-proof switch with paddle type actuator.

Paddle actuator heavy duty splash-proof switch.

The application of Human-Factors to the engineering design of heavy machinery and electronic panels and consoles is receiving more and more attention today because efficient mechanical performance usually depends on efficient human operation.

In selecting manual switches, the factors include size, operating feel and force, mounting means, method of actuation—such as pushbutton, toggle, rotary or rocker. In the MICRO SWITCH line there are hundreds of switches in many variations to meet nearly every possible Human-Factors requirement.

Available are varieties of circuitry, electrical capacities, terminals. For use under severe and hazardous environmental conditions, there are heavy-duty sealed and explosion-proof switches...and for customized panels, multi-circuit miniaturized pushbutton designs with miniature lamps under colored buttons.

No matter what your needs in switches, look to MICRO SWITCH. See the Yellow Pages for a nearby branch office or distributor. Or send for catalogs.

Left: An assortment representative of many families of finger and hand operated switches: Lighted pushbuttons, heavy duty designs, assemblies of pushbuttons and basic switch units, multiple circuit designs, and switches with a variety of electrical capacities and terminations.

MICRO SWITCH, FREEPORT, ILLINOIS
A division of Honeywell
In Canada: Honeywell Controls, Limited, Toronto 17, Ontario

Honeywell
MICRO SWITCH Precision Switches

Circle 217 on Page 19

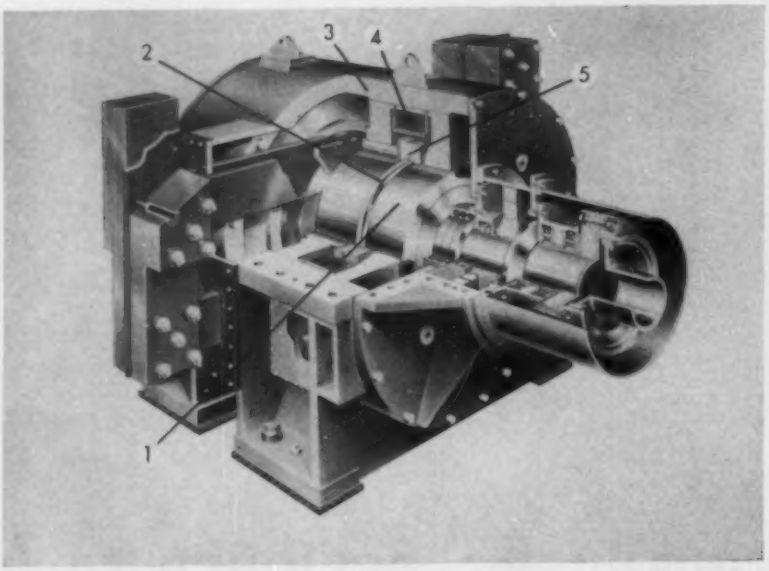
Half-Million-Amp DC Easy For Homopolars

SCHENECTADY, N. Y.—A new type of generator (based on an old idea) is proving to be an unusually efficient source of very high current, low-voltage dc. Called an acyclic generator by its developer, General Electric Co., the machine is also known as a homopolar, or unipolar, generator.

Four acyclic generators, each rated at 550,000 amp, 45 volts, are in service in a "hot-shot" wind tunnel at the Air Force's Arnold Engineering Development Center, Tullahoma, Tenn.

Faraday built a simple version of the homopolar device back in the 19th Century, but it never gained widespread use because of the complexity of sliding brushes required. The late Dr. Charles P. Steinmetz also experimented with acyclic generators and noted that they would have useful industrial applications if the problem of current collection could be worked out.

GE engineers have apparently solved the problem through the use of a liquid-metal collector system. In GE's generator, a solid-steel rotor, integral with the shaft, is surrounded by cylindrical stator poles. Liquid metal—a eutectic alloy of sodium and potassium—circulates between the rotating and stationary parts of the collector.



Key components in this half cutaway of the acyclic generator are: 1. Rotor. 2. Rotor-collector ring. 3. Stator. 4. Field coil. 5. NaK collector stator. Since NaK oxidizes rapidly, generators are enclosed and filled with dry nitrogen.

Typical characteristics of the acyclic generator include: High-speed operation (3600 rpm); high continuous current generation (150,000 amp); pure ripple-free dc output; and high peak-current capability.

Efficiency of the acyclic generator is above 98 per cent, compared to 94-95 per cent for conventional dc machines. It is a shunt generator with low regulation—5 to 7 per cent—comparable to that of a conventional dc machine. Excitation power required is very low—0.1 per cent compared to 0.5 per cent for conventionals.

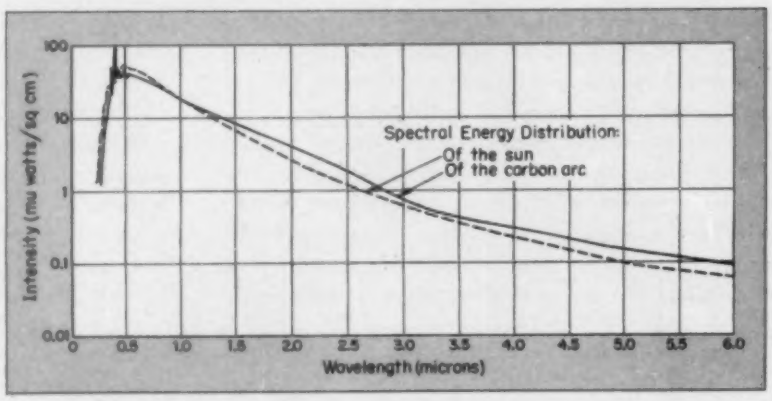
No main switchgear is required or desirable in the high-current circuits for which acyclic generators are applicable. The generators would be connected to their load circuits with only disconnecting switches or bus links.

All electrical parts of each generator are insulated from ground. Machines may be used separately or connected in any desired series or parallel combination.

Carbon Arc Radiates Near-Perfect Sunlight

Convenient Means of Solar Simulation Valuable Tool for Space Researchers

Wavelength for wavelength, two sources of light—the sun and a new carbon arc—produce nearly identical outputs across the entire frequency spectrum. Engineers at National Carbon Co., Div. of Union Carbide Corp., recently measured the frequency of a carbon arc all the way out to the 15-micron region. Curves (right) plotted in the 0.25-6 micron range (at least 98 per cent of the sun's output lies between these limits) show that the two sources have very similar spectral-energy distributions. According to National Carbon, space-equipment designers can now use banks of carbon arcs, with no filters or added energy, to prove out critical space-vehicle devices such as solar cells. The company also reports that special techniques have been developed for continuous operation of high-intensity arc carbons, thus assuring uninterrupted tests in space chambers.



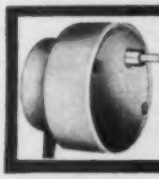
NEW BRISTOL SERIES 6100 TIME DELAY RELAY

7 TYPES OF LOAD CIRCUIT OPERATION ALL IN A SINGLE UNIT

Bristol's new Series 6100 gives you easy application with exclusive flexibility. No more complex wiring changes! Make circuit changes in a jiffy, too. You can reach the motor, and other parts—in seconds. The new "Bristol-Vision" dial is mounted in a square die-cast frame—provides better contrast for better viewing plus functional beauty too. Non-scratch bevelled *glass* dial cover won't buckle, deform—seals against dust. Powered by famous duty-matched standard Bristol motor. Write for brochure.

Contact the Bristol Distributor or Representative in your area.

SEND FOR HANDY TIMING CONTROL PRODUCT DIGEST —complete range of Bristol Motors, Timers and Timing Devices for all your timing and control applications.



LEADING SPECIALISTS IN AC AND DC MOTORS —from standard to special configurations designed to your specifications.

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- HOMOGENEOUS RUBBER—Natural and synthetic rubbers—especially compounded and processed for specific applications.
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All Chicago-Allis packings are available with *anti-friction* impregnations or coatings.

Whether it is a problem of higher pressures, higher temperatures, extreme operating conditions, or unusual compounds or liquids . . . or just a matter of plain efficiency, economy, and dependability . . . there is a Chicago-Allis packing especially suited for the application. C-A products are used across industry . . . automotive, aircraft, home appliances, agricultural equipment, machine tools, and ordnance equipment. Just ask for the assistance of C-A engineers who are always available for counsel on your packing requirements.

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Circle 219 on Page 19

Other-World Bacteria Worry Space Scientists

SUNNYVALE, CALIF.—If precautions aren't taken, microbes accidentally brought back from other planets might wipe out human life on earth, warns Lockheed Missiles and Space Co. The situation would be like one created in the South Pacific by eighteenth-century Europeans: Measles killed almost the entire population of several South-Sea islands; whooping cough and mumps were almost as deadly.

An intensive five-year program involving study of biological-decontamination techniques and development of sterilization units is proposed by Lockheed. The company has already designed and built the prototype of an ethylene-oxide/Freon-12 sterilizer for Ranger, the moon-landing vehicle, but bacteria can also be destroyed by other means—ultrasonic vibration, radiation, dry heat, extreme cold, dehydration, and even mechanical grinding. Research is needed in all these areas before the best methods can be chosen.

Sick Samples

Both living biological matter and specimens of rock, soil, and atmosphere are capable of carrying infectious material. Equally dangerous could be the unknown plant life that is picked up on film, tape records, and sampling instruments brought back from the surface of a foreign planet. This plant life could play havoc with the established order of life on earth, according to Lockheed.

All material coming back into a space craft must be sterilized, and, if possible, decontaminated. Sterilization could take place on the foreign planet or during the trip home, by remote-control mechanisms and procedures, or the job could be done on earth itself at a remote sealed-off station.

Two-Way Street

To guarantee that space explorers will find extraterrestrial life unchanged when man himself finally visits other planets, inadvertent seeding must be guarded against. Unless landing vessels are sterilized before they leave earth, it is possible they will destroy invaluable clues to the origin of the universe, according to Lockheed. Many secrets may be hidden under the atmosphere of other worlds, and deposits of earth's micro-organisms could render doubtful any evolutionary data that is gathered.

Meetings and Shows

Dec. 18—

Institute of the Aerospace Sciences. Wright Brothers Lecture to be given at the Smithsonian Institution, Washington, D. C. Additional information can be obtained from IAS, 2 E. 64th St., New York 21, N. Y.

Jan. 8-12—

Society of Automotive Engineers Inc. 1962 Automotive Engineering Congress and Exposition to be held at Cobo Hall, Detroit. Additional information can be obtained from society headquarters, 485 Lexington Ave., New York 17, N. Y.

Jan. 22-24—

Institute of the Aerospace Sciences. Thirteenth Annual Meeting to be held at Hotel Astor, New York. Further information can be obtained from IAS headquarters, 2 E. 64th St., New York 21, N. Y.

Jan. 22-25—

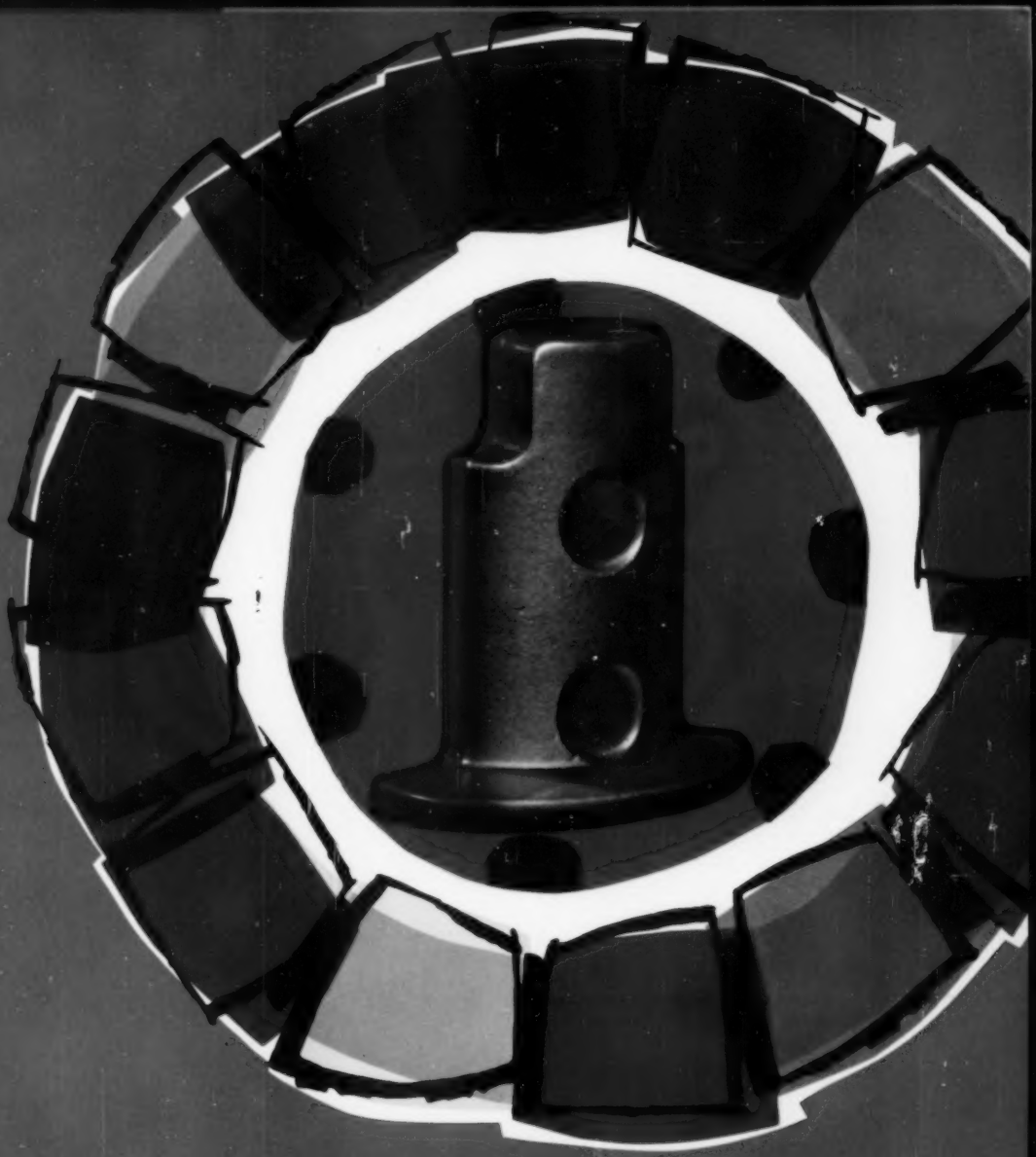
National Plant Engineering & Maintenance Show to be held at Convention Hall, Philadelphia. Further information can be obtained from show managers, Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.

Jan. 29-Feb. 1—

American Society of Heating, Refrigerating and Air-Conditioning Engineers. Semiannual Meeting to be held at the Chase-Park Plaza Hotel, St. Louis. Additional information can be obtained from ASHRAE headquarters, 345 E. 47th

(*Please turn to Page 41*)

Circle 220 on Page 19→



How a Value Analyst took 75% of the machining cost out of this generator part

Originally this rotor end plate was *not* a forged part.

Fully half the metal had to be machined off when the part was made by the original method. Many expensive rejects turned up when costly machining uncovered hidden flaws.

Value analysis led to redesign of the end plate as a forging. This produced a better part at a 50% reduction in material and a 75% reduction in machining costs.

See interesting details on next page.

FORGED

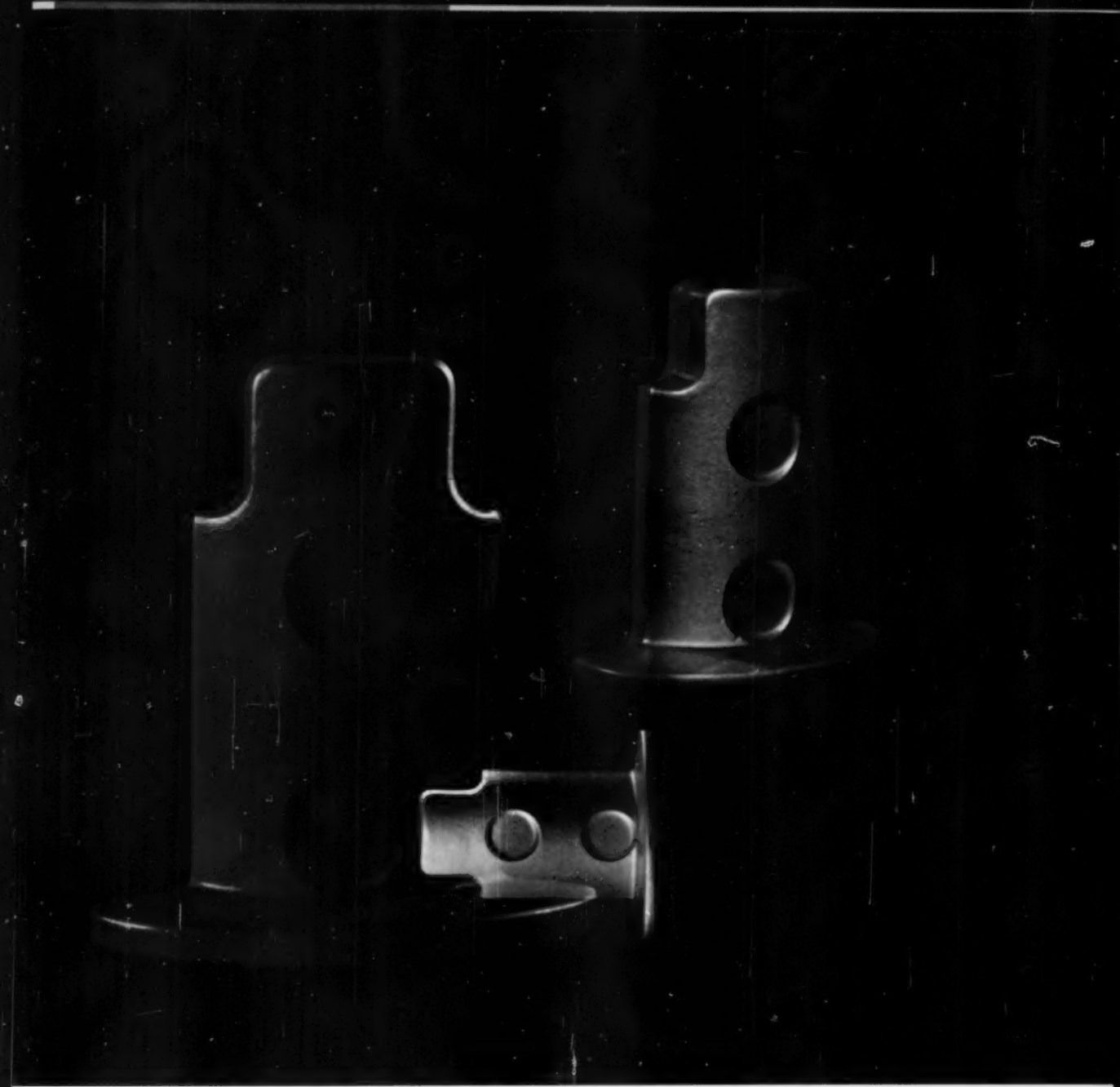
FOR RELIABILITY

Specifically...

the extra quality of this forging actually costs 60% less!

For the high-stress rotating mechanism of giant hydro-generators, *forged* end plates provided this combination of forging benefits:

1. Freedom from hidden flaws . . . because forgings in process never pass through the molten void-producing stage.
2. Selective grain structure oriented to counteract high-G centrifugal operating stresses . . . allowing thinner sections and smaller over-all size.
3. High tensile strength . . . 10% greater than former part.
4. Weight reduction . . . forging design eliminated 50% of the material required in former part.



The forged rotor end plates required far less machining. Three machining operations were completely eliminated, along with jigs and fixtures. This enabled the generator department to greatly reduce the shop area formerly required for machining.

Machine tools were released. Machinists were reassigned. Machining time was cut by 75%. These benefits, and others, were achieved by the conversion to forged end plates—even though quantity requirements were relatively low.

CASE STUDY REPORT

Analyze the detailed facts about this unique forging application. Write for the CASE STUDY REPORT complete with drawings, photographs, and full technical information —available without charge on request. Mail your request to Drop Forging Association • Dept. MD-2, 55 Public Square • Cleveland 13, Ohio.

When it's a vital part, design it to be FORGED

In modern forging plants, production and metallurgy are geared to modern ideas.

Steel and other metals are tested on arrival in this vacuum fusion gas-analysis apparatus. By heating samples and analyzing the oxygen and hydrogen liberated, metals are closely analyzed for compliance with specs.

This automatic template-controlled die-sinking machine is used to accurately reproduce contours of design in high-alloy steel forging die block.

A modern forging plant specializing in crankshaft forgings uses this mechanical integrator in its design room to determine centrifugal moments. Allocation of metal to counterweights is done with precision to achieve accurate balance.

THE FOLLOWING COMPANIES OF THE FORGING INDUSTRY HAVE SPONSORED THIS INFORMATIVE SERIES OF CASE STUDIES:

CALIFORNIA
California Drop Forge Company • Los Angeles, Calif.
Kortick Manufacturing Company • San Francisco, Calif.

CONNECTICUT
The Billings and Spencer Company • Hartford, Conn.
Wilcox-Crittenden Div., N. & J. Mfg. Co.
Middletown, Conn.

ILLINOIS
AmForge, Div. American Brake Shoe Co. • Chicago, Ill.
Clifford-Jacobs Forging Company • Champaign, Ill.
Commercial Stamping & Forging, Inc. • Chicago, Ill.
Cornell Forge Company • Chicago, Ill.
Englund Forge Company Inc. • Bensenville, Ill.
A. Finkl & Sons Co. • Chicago, Ill.
Forgings & Stampings, Inc. • Rockford, Ill.
Kropp Forge Company • Chicago, Ill.
Modern Drop Forge Co. • Blue Island, Ill.
Pettibone Mulliken Corporation • Chicago, Ill.
Rockford Drop Forge Co. • Rockford, Ill.
Standard Forgings Corporation • Chicago, Ill.
Taylor Forge & Pipe Works • Chicago, Ill.

INDIANA
Broderick Co., Div. of Harsco Corp. • Muncie, Ind.
Indianapolis Drop Forging Co., Inc. • Indianapolis, Ind.
Portland Forge, Incorporated • Portland, Ind.

MAINE
Thos. Laughlin Div., Amer. Hoist & Drk. Co.
Portland, Me.

MASSACHUSETTS
Cape Ann Tool Company • Pigeon Cove, Mass.
H. E. Holbrook Drop Forge, Inc. • Worcester, Mass.
Porter Forge & Furnace Inc. • Somerville, Mass.
Storms Drop Forging Company • Springfield, Mass.
Wyman-Gordon Company • Worcester, Mass.

MICHIGAN
Buchanan Steel Products Corporation • Buchanan, Mich.
Federal Drop Forge Company • Lansing, Mich.
Huron Forge & Machine Company • Detroit, Mich.
Michigan Forging Company • Dearborn, Mich.
Rockwell-Standard Corp., Forge Div. • Detroit, Mich.

NEW JERSEY
Garden State Forge Company • South Plainfield, N. J.

NEW YORK
The Brewer-Titchener Corporation • Cortland, N. Y.
The E. D. Clapp Mfg. Co., Inc. • Auburn, N. Y.
Endicott Forging & Mfg. Co., Inc. • Endicott, N. Y.
Merrill Brothers • Maspeth, N. Y.

OHIO
The Alliance Drop Forging Company • Alliance, O.
The Ashtabula Bow Socket Company • Ashtabula, O.
The Champion Rivet Company • Cleveland, O.
Columbus Bolt & Forging Co. • Columbus, O.
Eaton Manufacturing Co., Marion Div. • Marion, O.
The Harris-Thomas Drop Forge Co. • Dayton, O.
Poor & Co., Canton Forge & Axle Works • Canton, O.
H. K. Porter Co., Forge & Fittings Div. • Cleveland, O.
The Steel Improvement & Forge Co. • Cleveland, O.
Transue & Williams Steel Forging Corp. • Alliance, O.

PENNSYLVANIA
Duff-Norton Company • Pittsburgh, Pa.
Keystone Forging Co. • Northumberland, Pa.
The Lakeview Forge Company • Erie, Pa.
Pennsylvania Forge Company • Philadelphia, Pa.
Phoenix Mfg. Co., Div. Union Tank Co. • Catasauqua, Pa.
Pittsburgh Forgings Company • Coraopolis, Pa.
Wilcox Forging Corporation • Mechanicsburg, Pa.

RHODE ISLAND
Rhode Island Tool Company • Providence, R. I.

TEXAS
W. "Pat" Crow, Inc. • Fort Worth, Tex.
LeBus Mfg. Co., Amer. Hoist & Drk. Co. • Longview, Tex.
Trinity Forge, Inc. • Hurst, Tex.

WISCONSIN
Interstate Drop Forge Co. • Milwaukee, Wis.
Ladish Co. • Cudahy, Wis.
Milwaukee Forge & Machine Company • Milwaukee, Wis.
Unit Drop Forge, Div. Eaton Mfg. Co. • Milwaukee, Wis.
Walker Forge, Inc. • Racine, Wis.

CANADA
Canadian Warren Pink Limited • St. Catharines, Ontario
Dominion Forge Co., Div. Canman Ind. Ltd.
Windsor, Ontario

When it's a vital part, design it to be

FORGED

(Continued from Page 36)

St., New York 17, N. Y.

Jan. 30-Feb. 2—

Society of Plastics Engineers Inc. Annual Technical Conference to be held at the Penn-Sheraton Hotel, Pittsburgh. Further information can be obtained from John E. Parks, H.P.M. Div., Koehring Co., 512 Empire Bldg., Pittsburgh 22, Pa.

Feb. 6-8—

Society of the Plastics Industry Inc. Seventeenth Reinforced Plastics Division Conference to be held at the Edgewater Beach Hotel, Chicago. Further information is available from SPI headquarters, 250 Park Ave., New York 17, N. Y.

Feb. 15-17—

Golden Gate Metals Conference to be held at the Fairmont Hotel, San Francisco. Sponsor is American Society for Metals. Further information is available from Norman McLeod, 1605 Solano Ave., Berkeley 7, Calif.

Feb. 19-21—

Institute of the Aerospace Sciences. Range Reconnaissance & Tracking of Aerospace Vehicles Meeting to be held in San Francisco. Additional information is available from IAS headquarters, 2 E. 64th St., New York 21, N. Y.

March 4-8—

American Society of Mechanical Engineers. Gas Turbine-Process Industries Conference to be held at Shamrock Hilton Hotel, Houston. Further information is available from Meetings Dept., ASME, 345 E. 47th St., New York 17, N. Y.

March 27-29—

American Society of Mechanical Engineers. American Power Conference to be held at the Sherman Hotel, Chicago. Additional information is available from Meetings Dept., ASME, 345 E. 47th St., New York 17, N. Y.

March 28-31—

Eleventh Biennial Electrical Industry Show and Conference to be held at the Shrine Exposition Hall, Los Angeles. Sponsor is Electrical Maintenance Engineers Association of California. Further information is available from Mr. Fred J. Tabery, Exhibit Manager, 3443 South Hill St., Los Angeles 7, Calif.

April 9-13—

American Society of Mechanical Engineers. Metals Engineering Conference to be held at the Sheraton Cleveland Hotel, Cleveland. Additional information is available from Meetings Dept., ASME, 347 E. 47th St., New York 17, N. Y.

Short Courses and Symposia

Seminars on Numerical Control will be conducted jointly by the National Machine Tool Builders' Association and American Machine Tool Distributors Association. Dates and locations are as follows: Jan. 8-9, Statler Hilton Hotel, Cleveland; Jan. 11-12, Netherlands Hilton Hotel, Cincinnati; Jan. 22-23, LaSalle Hotel, Chicago; Jan. 25-26, Sheraton-Cadillac Hotel, Detroit; Feb. 5-6, Marriott Motor Hotel, Philadelphia; Feb. 8-9, Hotel Kenmore, Boston; Feb. 19-20. The Dinkler Plaza, Atlanta; Feb. 22-23, Hotel Adolphus, Dallas. Other seminars will be scheduled. Further information is available from Mr. Arthur Hachten, Director of Information Services, National Machine Tool Builders' Association, 2139 Wisconsin Ave., Washington 7, D. C.

Jan. 9-11—

Eighth National Symposium on Reliability and Quality Control to be held at the Statler Hilton Hotel, Washington, D. C. Technical sessions will cover reliability and design techniques, reliability prediction and measurement, mathematics and reliability models, statistical techniques, reliability testing, maintainability, quality control and reliability, reliability programs and management, reliability and quality control education, and reliability training sessions. Additional information can be obtained from Mr. A. R. Park, Mail Stop No. 729, Westinghouse Electric Corp., P. O.

Waterman Series 1407 is a group of compact, low-cost, pressure-compensated flow regulators, adjustable over a series of unusually wide flow ranges, for convenient on-the-job speed control of hydraulic cylinders and motors.

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Controlled flow to 40 g.p.m.—ideal for hydraulic motors as well as cylinders. Factory-tested to 10% tolerance.

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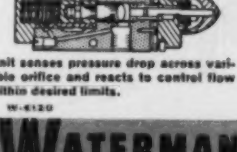
Choice of mountings and operating devices.

¼" N.P.T.F. size meets most needs—standard sub-plate mountings available.

Compact and light in weight—proved to be trouble-free in thousands of applications.



Unit senses pressure drop across variable orifice and reacts to control flow within desired limits.

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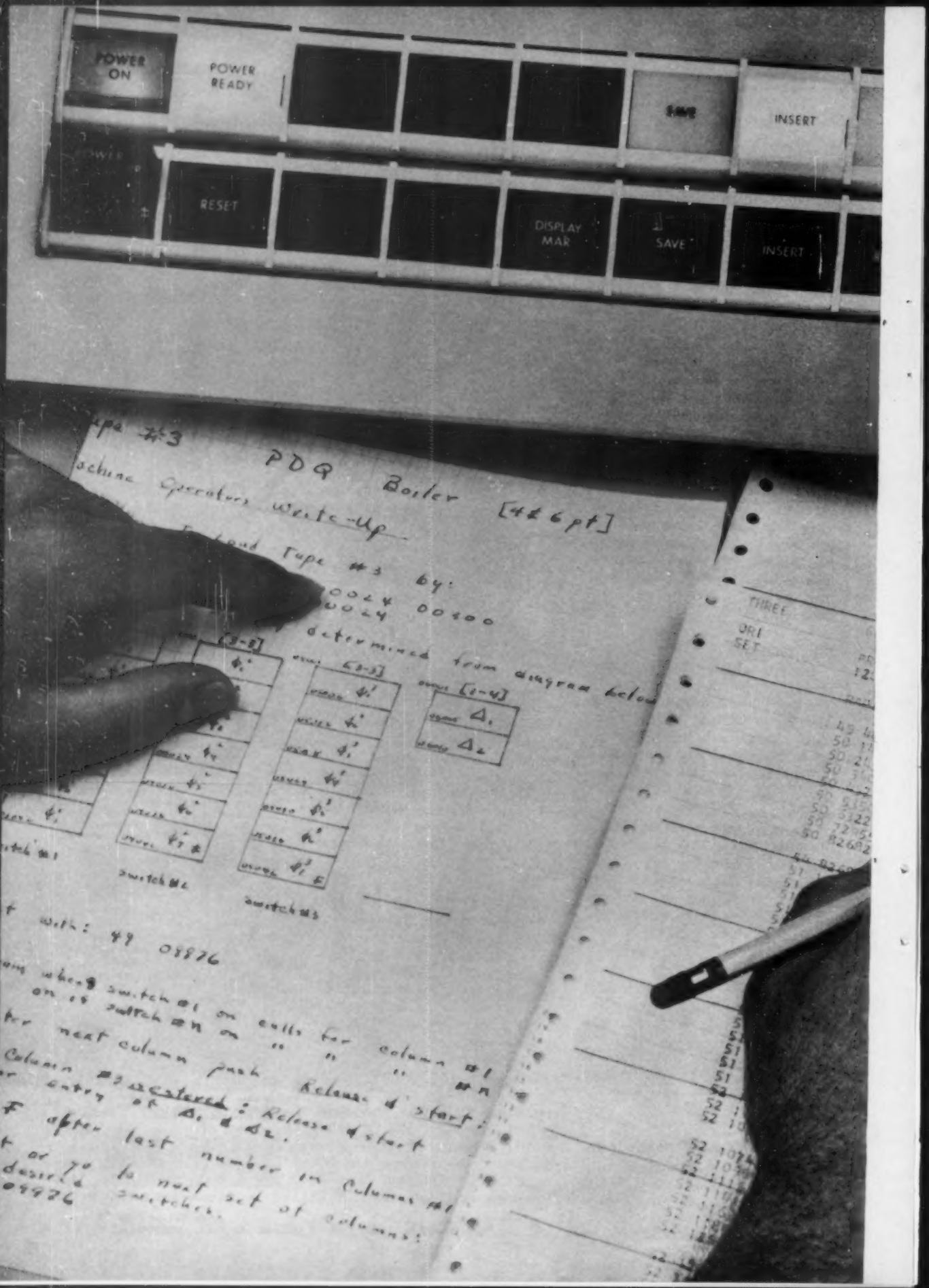
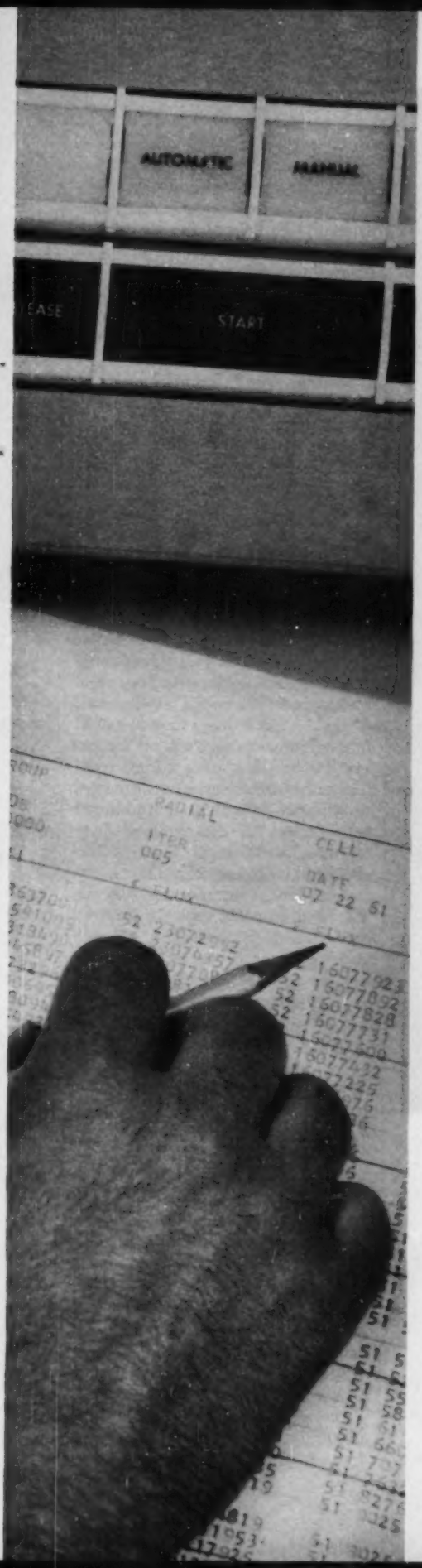
Circle 221 on Page 19

←Circle 220 on Page 19


POWER ON
POWER READY
INSERT
RESET
DISPLAY MAR
SAVE
INSERT
PDQ Boiler [4 & 6 pt]
Machine Operators Write-Up
switch #1
switch #2
switch #3
THREE
ORI
SET



Cost of one-dimensional criticality computations drops from an average of $75.00 to $7.50 per problem

Faster computing, less travel time are the reasons why General Nuclear Engineering Corporation has realized such cost savings since it installed an IBM 1620 Data Processing System at its Dunedin, Florida plant.

Since its main computing facilities are not located at Dunedin, General Nuclear has found that the new 1620 eliminates much of the travel time and expense involved in taking problems to off-site computers. In addition, the 1620 performs the simpler criticality computations 10 times faster than the computer previously used at one of General Nuclear's off-site data processing centers.

General Nuclear uses its new 1620 for other problems, too...heat transfer calculations, various transient codes, mathematical routines for the physics and engineering departments, multi-group calculations, and many other jobs you might expect only a much more expensive computer to be able to handle.

This isn't all. General Nuclear uses the 1620 to do statistical analyses and variance calculations on input data for programs run on off-site large-scale IBM computers.

For information on this highly versatile, low-cost data processing system, which rents for as little as $1600 a month, contact your local IBM Representative.

Easy to program. FORTRAN, IBM's scientific computer language is available for the 1620. General Nuclear scientists use a special scientific interpretive program—FIDO—written by the Manager of their Computing Section.

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DATA PROCESSING

Circle 222 on Page 19

Box No. 1897, Baltimore 3, Md.

Jan. 11-12—

Electrical Engineering Refresher Course to be held at the University of Wisconsin. Further information is available from Engineering Institutes, 3030 Stadium, University of Wisconsin, Madison 6, Wis.

Jan. 15-19—

Seminar on Simulation and Mathematical Programming for industrial engineers, to be held at the University of Wisconsin. Further information is available from Engineering Institutes, 3030 Stadium, University of Wisconsin, Madison 6, Wis.

Jan. 16-17—

Engineering Institute on Industrial Adhesives Applications to be held at University of Wisconsin. Technical sessions will cover basic principles of adhesive bonding, some important applications of adhesives, design of joints for adhesive bonding, equipment requirements for adhesive bonding, evalution techniques for adhesives, and principles of adhesive formulation. Additional information can be obtained from William W. Wuerger, Institute Coordinator, Engineering Dept., Extension Div., University of Wisconsin, Madison, Wis.

Jan. 18-19—

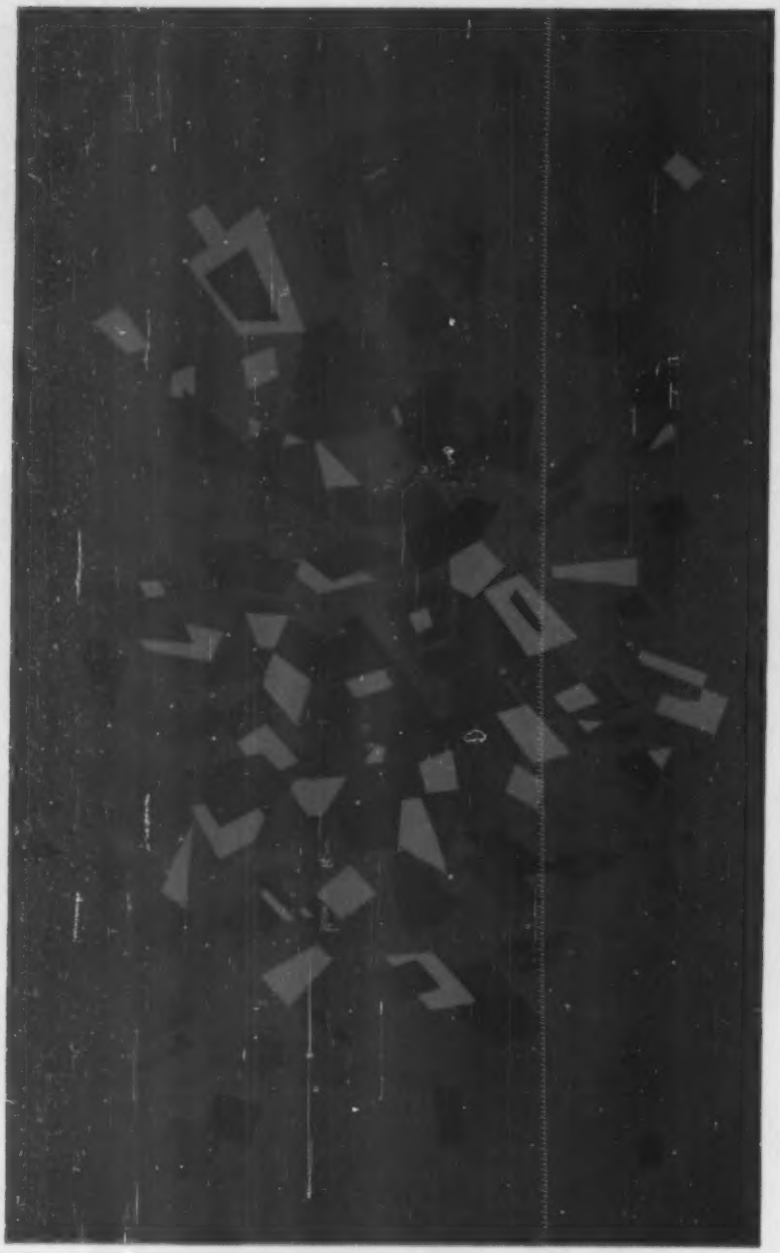
Industrial Power Systems Seminar to be held at the University of Wisconsin. Further information is available from Engineering Institutes, 3030 Stadium, University of Wisconsin, Madison 6, Wis.

Jan. 24-26—

Second Symposium on Thermophysical Properties to be held in Princeton, N. J., under the auspices of the Heat Transfer Div. of the American Society of Mechanical Engineers. Further information can be obtained from ASME, 345 E. 47th St., New York 17, N. Y.

Jan. 24-26—

Second Symposium on Thermoplastic Properties to be held at Princeton University, Princeton, N. J. Technical session topics are: Ionized gases, thermodynamic prop-



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Circle 223 on Page 19

erties, transport properties—theoretical, thermodynamic equilibrium, radiation, computational methods, non-Newtonian fluids, experimental techniques, intermolecular forces and interactions, equations of state, and transport properties—experimental. Additional information is available from Mr. H. Bainbridge, Glenbrook Laboratories, Div. of Sterling Drug Co., P. O. Box 1536, Trenton 7, N. J.

Jan. 25-26—

Research Management Conference to be held at University of Wisconsin. Additional information is available from C. F. Hurc, Conference Co-ordinator, University Extension Div., Dept. of Engineering, University of Wisconsin, Madison 6, Wis.

Jan. 29-Feb. 2—

Short Courses on Measurement Engineering to be held at Arizona State University. Theme of the courses is "How To Obtain Valid Data on Purpose"; they consist of a lecture program and a concurrent experimental program. About half of the lectures are on basic physical principles on which transducers are based and on fundamental measurement theory, including static and dynamic system behavior and the correlation between them. The other lectures are devoted to measurement problems and approaches in specific areas. Additional information is available from Prof. Peter K. Stein, Associate Professor of Engineering, Measurement Engineering, Engineering Center, Arizona State University, Tempe, Ariz.

Jan. 30-Feb. 1—

Seminar on Standardization to be held at the Barbizon Plaza Hotel, New York. The seminar will cover fundamental philosophy of organized standardization and an analysis of the basic approach to the formation of standards; a review of standardization as an integral function of management and the organization of standards work, particularly on the company level. Further information is available from Dr. John Gaillard, 135 Old Palisades Rd., Fort Lee, N. J.

iTi IS A BALL
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An ancient ivory chess queen—at its base seven balls diminishing in size, each painstakingly carved through holes in the others.

A precision ball, one of millions produced by Industrial Tectonics, Inc.—their sphericity precise to .000005 of an inch, their uniformity to .000010 of an inch and their surfaces smooth to 1 microinch.

Carving the seven ivory balls took long experience and special skill. Manufacturing ultra-precision balls—of over a hundred different materials and precise to millionths of an inch—demands a different application of the same timeless qualities.

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The Precision Ball is Precisely Our Sphere
Ball Division • Dept 11 • 3684 Jackson Road • Ann Arbor, Michigan

Circle 224 on Page 19

HIGH-SPEED SWITCHING

Check these CLARE Mercury-Wetted Relays against your design needs

Choice of two basic switches

SPEED TO 200 CPS

This CLARE TYPE HGS is the fastest operating, most sensitive mercury-wetted contact relay obtainable. It will operate at speeds to 200 cps with sensitivity as low as 2.5 milli-watts with a contact rating of 2 amperes, 500 volts (100va max.). Two permanent magnets provide single-side stable and bi-stable adjustments. Available with Form D (bridging) contacts.

LOADS TO 250 VA

This CLARE HG capsule will handle contact loads as high as 5 amperes, 500 volts (250va max.). Operating time may be as low as 3 milliseconds. It is also available equipped with two permanent magnets (HGP TYPE) for single-side stable, bi-stable or chopper operation.

The Clare Mercury-Wetted Relay Principle

The remarkably long life of CLARE mercury-wetted relays is the result of a design principle whereby a film of mercury on the contacts is constantly renewed, by capillary action, from a mercury pool. Both CLARE HGS and HG switch capsules employ this principle. Both switches are sealed in high-pressure hydrogen atmosphere. Certain construction differences, however, give greater speed and sensitivity to the HGS switch.

FOR BILLIONS OF OPERATIONS

Choice of three convenient packages

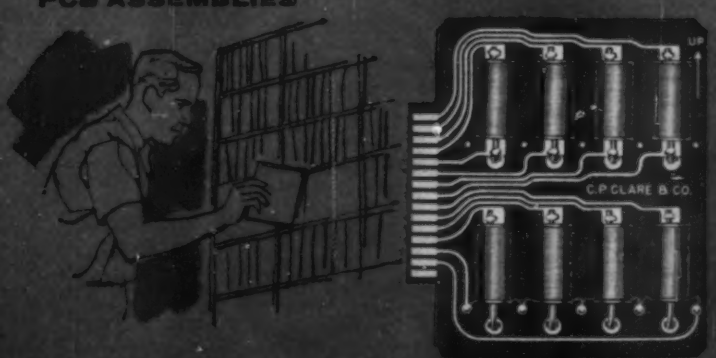
ENCLOSED MODULES

Both CLARE HGS and HG switch capsules are available in steel-enclosed modules for convenient mounting on printed circuit boards in the same manner as resistors, capacitors and similar components. The enclosure is ruggedly designed and provides both excellent mechanical protection and magnetic shielding. These modules are ideal for design and prototype work.

CONVENTIONAL PLUG-IN RELAYS

CLARE HGS switch capsules are available in single switch units, surrounded by a coil, mounted in high-melting point wax and encased in cylindrical steel containers provided with plug-in base. A smaller type (HGSS) is designed for use where space is limited. HG relays are available with one, two, three, or four capsules, surrounded by a single coil. Also with permanent magnets (HGP) for single-side stable, bi-stable or chopper operation.

PCB ASSEMBLIES



Printed circuit board assemblies are available with either HGS or HG switch capsules to meet design specifications. These may be designed to customer specifications by CLARE or mounted on boards supplied by the customer. Number of relays is limited only by the dimensions of the printed circuit board.

NEW! Design Manual 201A

Complete data on characteristics, circuitry, mountings, coil tables and information for ordering CLARE mercury-wetted contact relays.

See your nearest CLARE representative or address: C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Canada Ltd., 840 Caledonia Road, Toronto 19, Ontario. Cable Address: CLARELAY.

C. P. CLARE & CO.

Relays and related control components

Circle 225 on Page 19

WE BROKE A DOZEN SCREWS, BUT

we couldn't make this sheet metal insert spin in its hole!

THE INSERT PROBLEM

A hole punched in thin sheet metal doesn't provide enough surface for threading. You often have to supply the threads by installing an insert.

But the same hole doesn't provide much surface for *gripping*, either. The insert spins.

WHAT WE DID ABOUT IT

The insert we tested was designed with an *angular* knurl around a cone-shaped gripping perimeter. Here's what happened:

First: When we mated the sheets, put in a screw, and tightened it in the insert, the screw pulled the insert toward the sheet. It also pulled the teeth of the angular knurl more firmly into the edges of the hole, increasing their resistance to spin.

We broke screws (No. 8, 10, 12, and ¼ sizes) by overtorquing them. But the only effect on the insert was to tighten it.

Second: When the insert was first pressed into the hole, the angular knurl displaced metal, squeezing it toward and into a groove around the bottom of the insert. This locked the insert against being pushed out before the screw was tightened. After tightening, the lock was intensified by the added squeezing pressure of the angular knurl.

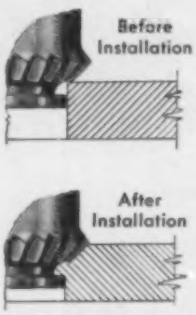
WE'LL SEND SAMPLES

If you've had this insert problem, drop us a line on your letterhead. We'll send some Southco THREDS (that's their name) for you to try. No obligation, of course. Write Southco Div., South Chester Corporation, 237 Industrial Highway, Lester, Pa.

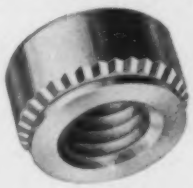
THREDS . . . AND THE ANGULAR KNURL PRINCIPLE

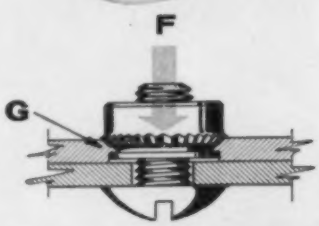
Southco THREDS are installed by pressing into a single hole in the sheet, provide thread length equal to or greater than that of a standard nut. One insert fits any sheet thickness (see minimum requirement, last column in table below). Material is case hardened steel, Cad. plated per Fed. Spec. QQ-P-416 Type II, cl. 2, yellow iridite.

ANGULAR KNURL
(detail)

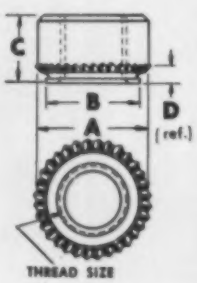


Teeth bite into edge of hole, force metal into locking groove at base of insert.





Additional torque on screw increases force F, pulling teeth of angular knurl more firmly against sheet and putting extra pressure on metal in locking groove G.



SOUTHCO THREDS[T.M.] . . . SPECIFICATIONS

THREAD SIZE	PART NUMBER	A	B	C	D	Weight per M (lbs.)	Min. Sheet Thickness
4-40 NC	74-11-104-13	3/32	.185	3/32	3/64	1.22	.036
6-32 NC	74-11-106-13	3/32	.247	3/32	3/64	1.89	
8-32 NC	74-11-108-13	1/8	.278	3/32	3/64	2.87	.048
10-24 NC	74-11-110-13	1/8	.278	3/32	3/64	2.51	
10-32 NF	74-11-210-13	1/8	.278	3/32	3/64	2.53	
12-24 NC	74-11-112-13	13/64	.372	3/32	1/16	4.56	.060
¼-20 NC	74-11-125-13	13/64	.372	3/32	1/16	4.28	
¼-28 NF	74-11-225-13	13/64	.372	3/32	1/16	4.32	

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SOUTHCO FASTENERS

LION

These are only a few of the Licon type 16 subminiature switches available.

LICON®

TYPE 16 SUBMINIATURE SWITCHES

PROVED BETTER 3 WAYS

LONGER LIFE . . . No other subminiature switch can equal the performance and long service life of the Licon Type 16. Only ¼" thick and 25/32" long, the Licon Type 16 delivers over 20,000,000 operational cycles without mechanical failure. This has been repeatedly test-proved. Quality and uniform dependability make the Type 16 superior to *any* subminiature switch.

HIGHEST ELECTRICAL RATING . . . The tiny Type 16 is rated at 10 Amps, 30 volts d-c inductive. This rating, the highest among subminiatures, is achieved with a unique double-break mechanism that effectively increases electrical performance, and life, as well as capacity. Arc energy and heat dissipation are distributed over two places, minimizing the possibility of contact weld. Double-break design offers multiple circuit possibilities not available in other subminiatures. The Licon Type 16 finds wide acceptance in aircraft and missile applications yet is economically adapted to industrial use. Its rating, dependability and performance equal those of a big switch, but its compact size makes it an excellent choice for use where critical space and weight limitations exist.

VERSATILITY . . . Type 16 switches come in reset, momentary, and specially engineered styles. Leaf spring, lever, roller, plunger or combination actuators are standard. Terminals may be solder, screw, or taper tab and may extend from the bottom, sides, or ends of the switch case. Variations of the Type 16 will be engineered to your specification.

THIS CATALOG IS YOURS *on request.*
It gives dimensional data and engineering "specs" on the Type 16 and the whole broad Licon line. Send for yours today.

NOTE: *Standard Type 16 Switches and Actuators are available through your local Licon distributor.*

✻ TYPICAL PROVED APPLICATIONS . . .

Licon Type 16 subminiature switches are presently in use in missile detonators, sensing devices on automatic machine tools, automatic postal equipment, speed control devices, communication equipment, coin changer equipment, automatic door openers, relay actuation, and a host of airborne controls, including hermetic and environment-free units.

itw LICON

DIVISION ILLINOIS TOOL WORKS INC.
6615 W. IRVING PARK ROAD, CHICAGO 34, ILLINOIS

Circle 227 on Page 19

FLANGE PROJECTIONS improve TORQUE RETENTION

Here's a simple, economical, and widely adaptable way to build elasticity into rigid flange-bolt assemblies . . . and get better torque retention.

E. M. SMOLEY, Research Physicist, Armstrong Research and Development Center

To minimize loss of bolt torque in rigid gasketed joints, design engineers try to introduce some elasticity into the flange-bolt system.

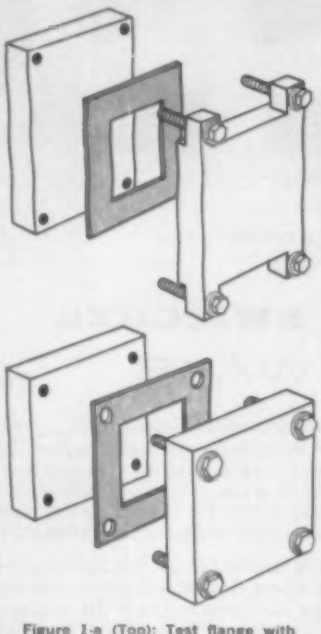


Figure 1-a (Top): Test flange with gasket. Note cantilevered projections for bolt holes. Flanges 1" thick, with gasket area 4" square.

Figure 1-b (Bottom): Control flange with gasket area 4" square.

One way to do this is to use the longest bolts possible, torqued close to their recommended limits. The elasticity of the bolts (the so-called "spring effect") then acts to compensate for compression drift and the effects of thermal expansion.

In most applications, however, long bolts are either impractical or uneconomical. As alternates, designers may use spring-loaded bolts or through bolts with nuts. These will usually produce the desired elasticity, but they increase parts costs and add to assembly time.

Armstrong research engineers suggest the use of cantilevered projections as a simple, economical, and widely adaptable way of building elasticity into a rigid flange.

Figure 1-a shows a laboratory design of such a flange. The machined projections through which the bolts pass do not contact the bottom flange. As the bolts are tightened, the projections deflect slightly, introducing elasticity through the flange instead of through the bolts.

This design was tested extensively at the Armstrong Research and Development Center. A control flange of identical size except for the projections was tested simultaneously (Figure 1-b).

Both flanges were gasketed with an Armstrong Accopac® asbestos material (1/32") and assembled with four 5/16" NF bolts. In the initial test, all bolts were torqued to 5 pound-feet, and both assemblies were placed in a 300° F. oven.

After 18 hours, retained torque was measured (1) while the flanges were still hot; and (2) when they had cooled to room temperature.

The test was repeated, increasing the torque in increments of 5 pound-feet up to 25 pound-feet. A summary of the test data is given in Figure 2.

TORQUE RETENTION

POUND FEET INITIAL TORQUE	HOT TORQUE CONTROL	HOT TORQUE TEST	COLD TORQUE CONTROL	COLD TORQUE TEST
5	3.6	4.5	3.0	3.6
10	6.4	9.8	6.2	8.9
15	10.0	14.4	10.0	14.0
20	14.8	20.2	13.2	19.6
25	18.2	25.6	18.2	24.8

Figure 2: Results of flange projection study. Hot torque measured after 18 hours at 300° F. Cold torque measured after cooling to room temperature. Accopac AN-890 asbestos gasket (1/32") in flanges.

In every case, the test flange shows a higher torque retention—hot or cold—than the control flange. At loads of 15, 20, and 25 pound-feet, practically 100% of the initial torque load was retained on the test flange.

Research on problems of gasket selection, design, and performance is a continuing project at the Armstrong Research and Development Center. Our large library of data may already contain answers to your specific sealing problems. We will be glad to make suggestions if you will send details to us. Armstrong Cork Company, 7112 Dean Street, Lancaster, Pa.

Armstrong GASKET MATERIALS

BEST for... SPLIT-SECOND TIMING

for laboratories • production control • test equipment • time-motion studies wherever precise measurements are needed!

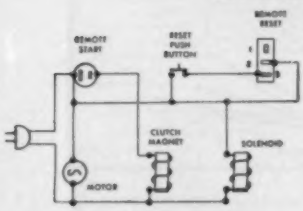
ELECTRIC STOP-CLOCK

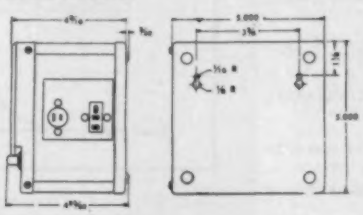
SC 100

with exclusive new INSTANT STOP Cone Clutch

Now stop-clocks go versatile—with the SC 100, the ideal timing instrument where short, precise measurements are required. It starts, stops and resets automatically in milliseconds. The SC 100 features a unique cone clutch which engages the pointer mechanism with the synchronous motor. So rapid is the clutch engagement that no dial compensation is required for pull-in lag. An additional feature is a solenoid-operated pointer reset which completes a full dial reset in approximately 100 millseconds. A compound dial is employed using two pointers, the inside dial registers from 1 to 60 seconds in 1 second increments. The outside dial measures from .01 to .99 seconds in .01 second calibrations. Write for Bulletin #702 and get the full details why this is the timely answer to your timing problems.

ENGINEERING SPECIFICATIONS





The SC 100 Electric Stop-Clock is only one example of the thousands of precision engineered timing controls contained in our 50-page, fact-packed catalog. It will pay you and your firm to have a copy of this valuable volume. For a free copy, write us on your company's letterhead.

INDUSTRIAL TIMER CORPORATION

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Circle 228 on Page 19

UP TO THE MINUTE IN DESIGN DOWN TO THE SPLIT SECOND IN ACCURACY!

SERIES TDAB TIME DELAY TIMERS

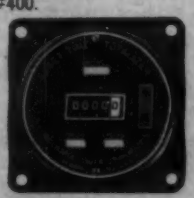
Designed for applications on circuit controls where an adjustable or fixed time delay is required between the opening or closing of one circuit and the predetermined opening or closing of another circuit. Back mounted and automatic reset. Write for Bulletin #300 for full details.

SERIES MC PROGRAM CAM TIMERS

Repeats a continuous, adjustable ON and OFF electrical cycle. Standard cam construction is such that the ON-OFF cycle can be adjusted from 2% to 98% of the total time cycle. Individual cam adjustability enables the timer to be used as a programming device with up to 20 switches. Cams can be adjusted, rapidly and easily, in any combination of timed sequences. Write for Bulletin #200.

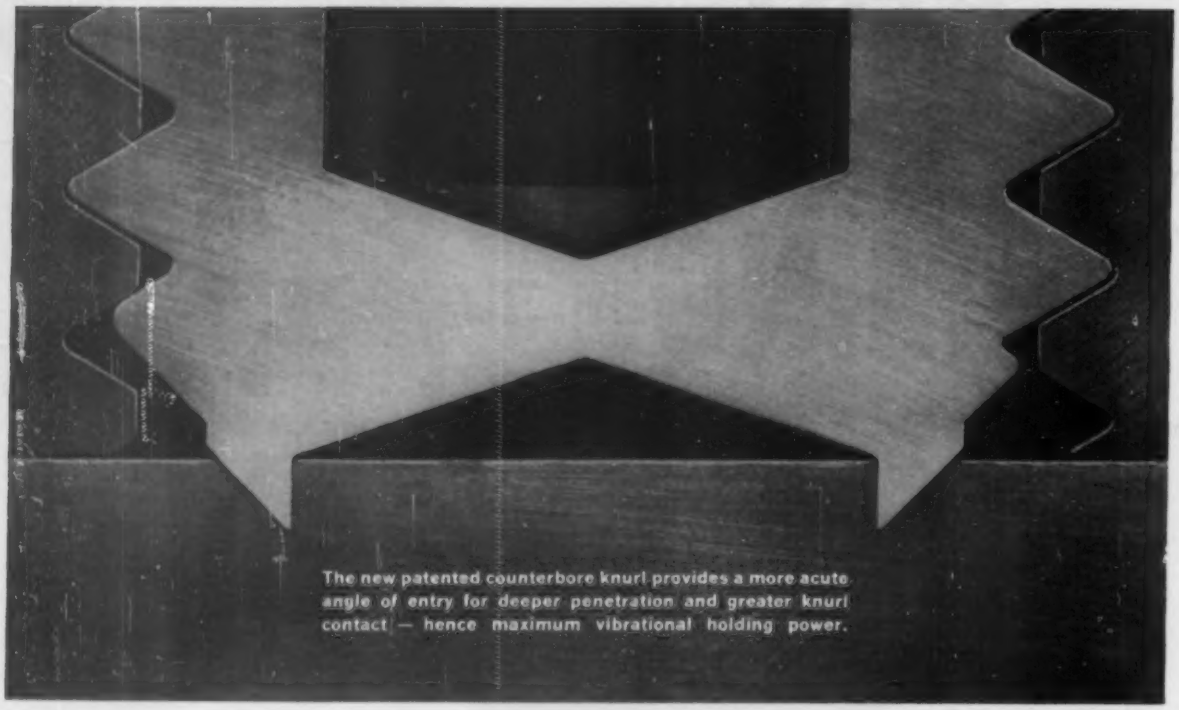
SERIES PAB INTERVAL TIMERS

Close a load circuit for a pre-set time interval. Automatically resets at the completion of the time cycle. Extremely accurate timing mechanism built to stand up under the hard usage and demanding standards that modern manufacturing processes require. Write for Bulletin #400.



MODEL C-5 RESET TIME TOTALIZER

Provides extreme accuracy where elapsed time meters are required to show an exact record of machine operating hours. Reset wheel protrudes slightly out front of panel for easy thumb adjustment. Precision engineered throughout according to Industrial Timer standards. Write for Bulletin #700 for details.



The new patented counterbore knurl provides a more acute angle of entry for deeper penetration and greater knurl contact — hence maximum vibrational holding power.

NOW! Vibrational holding power hits a new high!

. . . which means that your designs can now become even more *reliable*, for the new UNBRAKO set screw with patented* counterbore knurl is "the one that won't work loose." What's more, you gain in *simplicity* (no need to use two screws since one will do the job) and in *flexibility* (no need to use a permanent pin fastening where you'd prefer a readjustable set screw).

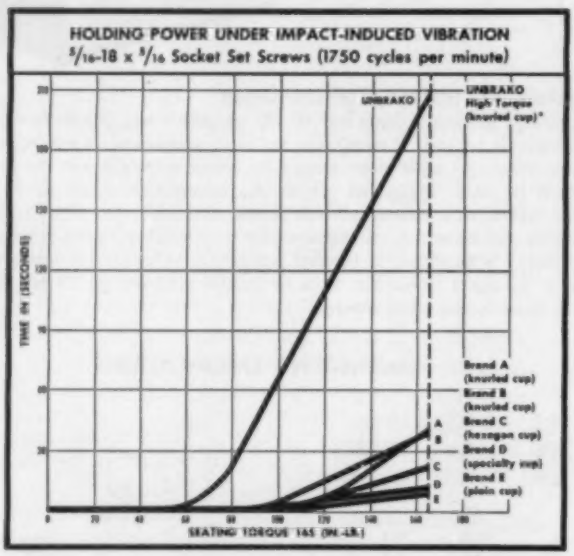
The new UNBRAKO High Torque is two ways tighter than any other socket set screw. First, the new counterbore knurl produces deeper shaft penetration. This is precisely what you need and want in order to achieve positive locking action *before* . . . and unparalleled vibrational holding power *at* the recommended seating torque.

Second, UNBRAKO's seating torques are up to 40% higher than those of ordinary set screws, and the tighter a screw is wrenched the greater its holding power. Behind UNBRAKO's higher torques:

- Exclusive Hi-Life thread root that distributes stress concentration at critical area
- Fully formed threads with metal compressed into a closely knit grain structure
- Deeper sockets for maximum key engagement and wrenching power
- Precision heat-treated steel to eliminate brittleness or decarburization

As you can see from the graph, the new UNBRAKO offers vibrational holding power no other set screw can begin to achieve—*throughout the entire torquing range.*

The new UNBRAKO High Torque Set Screw—with counterbore knurl and Hi-Life threads—is available in sizes #4 through 1 in. Your authorized UNBRAKO distributor has a complete supply on hand *now*. Where shaft penetration is undesirable, specify UNBRAKO with Nylok.† For a copy of our new booklet on UNBRAKO High Torque Set Screws, write to Standard Pressed Steel Co., INDUSTRIAL FASTENER DIVISION, SPS, JENKINTOWN 18, PENNSYLVANIA.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UNBRAKO High Torque (knurled cup)*
Brand A (knurled cup)
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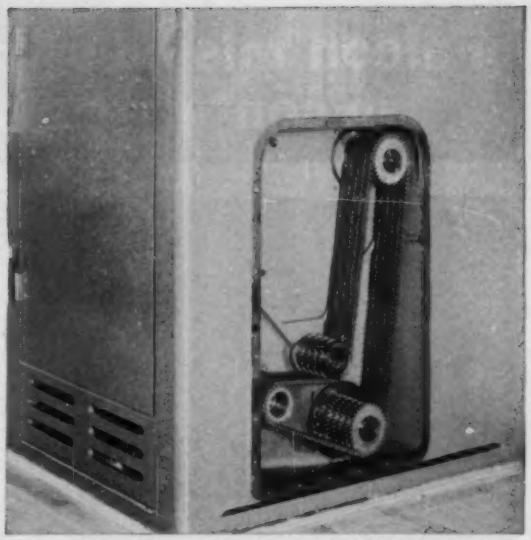
Brand E (plain cup)
TIME IN (SECONDS)
SEATING TORQUE LBS (IN.-LB.)

*No. 2,992,669—patented July 18, 1961 †T.M. Reg. U.S. Pat. Off. The Nylok Corp.

SPS

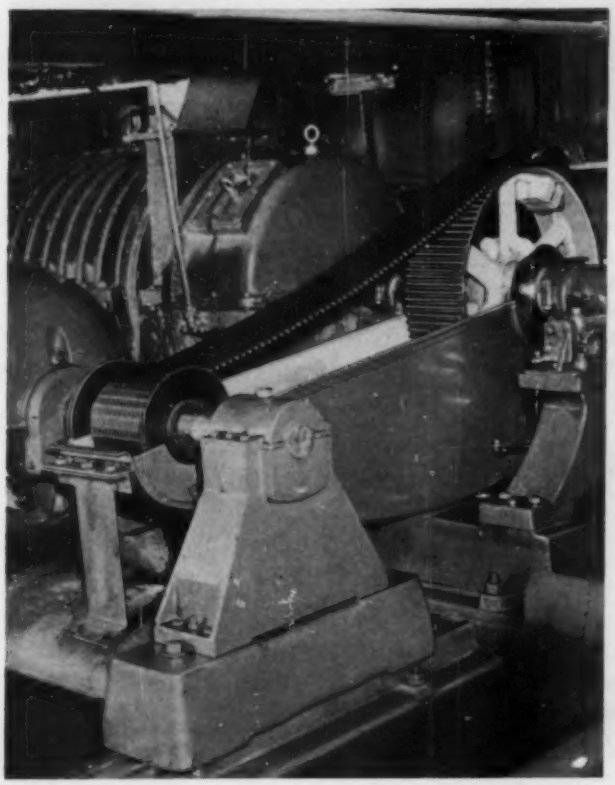
where reliability replaces probability



FOR DRIVING A SERIES OF SHAFTS on fixed centers, Link-Belt silent chain assures positive transmission of power. On applications requiring reverse rotation of shafts, Link-Belt duplex silent chain is capable of driving wheels from either side of chain.

Link-Belt silent chain

for drives that can't afford to slip



Smooth, positive engagement assures full power transmission

Continuous, nonslip operation for many years with only routine attention—this is a common experience with Link-Belt silent chain. Where other types of drives are impractical due to slipping tendencies, this modern chain drive delivers positive transmission of full-rated horsepower.

Link-Belt silent chain assures efficiency for either large or fractional-horsepower drives. Easy assembly in tight spaces permits built-in drives, compact housings. Close grouping of equipment saves valuable floor space. High humidity, temperature have no effect on performance. Ratios as high as 10-to-1 are accommodated on relatively short centers.

Available in a full range of sizes. For complete information, call your nearby Link-Belt office. Ask for Book 2425.

WHERE SPACE IS LIMITED, compact Link-Belt silent chain drives permit close grouping of equipment. High ratio reductions are easily accommodated on relatively short centers.

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LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Warehouses, District Sales Offices and Stock Carrying Distributors in All Principal Cities. Export Office, New York 7; Australia, Marrickville (Sydney); Brazil, Sao Paulo; Canada, Scarboro (Toronto 13); South Africa, Springs; Switzerland, Geneva. Representatives Throughout the World.

Circle 230 on Page 19

Falcon missiles travel "first class" in containers secured by LINK-LOCK

Fourteen No. 2 LINK-LOCK fasteners → maintain a pressure-tight seal around cover of Falcon cases.

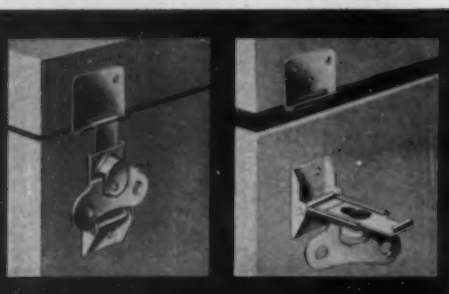
Before they take to the skies, Falcon air-to-air guided missiles are shipped or stored in containers sealed pressure-tight by Simmons LINK-LOCK fasteners.

These precisely engineered fabricated aluminum cases are produced to Hughes Aircraft Company specifications by the following companies: Vendorlator Manufacturing Co., Fresno, California; Allison Steel Manufacturing Co., Phoenix, Arizona; Avco Corporation, Crosley Division, Richmond, Indiana.

Features like these make the LINK-LOCK ideal for use on military cases made to rigid specifications as well as on inexpensive commercial containers:

- Impact and drop resistant.
- Positive-locking without springs.
- High preloading and high load carrying capacity.
- Compact design—lies flat open or secured.
- 3 sizes, for heavy, medium, light duty.
- Flexible engagement latch design... can be varied to suit different applications.

Write for Catalog #760. Contains complete details of LINK-LOCK and other Simmons Fasteners with unlimited money-saving applications. Samples and engineering service available on request.



Half-turn applies high closing pressure, counter-turn disengages for opening. LINK-LOCK lies flat open or closed.

SIMMONS

FASTENER CORPORATION

North Broadway, Albany 1, New York

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DUAL-LOCK • HINGE-LOCK

USS 9% Nickel Steel reduces cost of handling low-temperature liquids

Today, more than 400 pressure vessels made of 9% nickel steel are providing economical service at temperatures down to —320°F, the boiling point of liquid nitrogen. The pressure vessel shown here is designed for liquid oxygen storage at —297°F. Low carbon, 9% nickel alloy steel was developed to provide a ductile, moderately priced steel for storing such cryogenic liquids as ethylene, methane, oxygen and nitrogen in the temperature range from —150°F to —320°F.

USS 9% Nickel Steel maintains good strength, toughness, and excellent ductility at sub-zero temperatures down to —320°F. At room temperature it has a minimum yield strength of 65,000 psi and high charpy impact values, while at —320°F, double-normalized and tempered 9% nickel steel shows a 36% increase in yield strength, and charpy keyhole impact values range from 20 to 40 ft/lbs. Since tensile properties and impact values are even better for quenched and tempered 9% nickel steel, recognition by various code groups of the suitability of such heat treatment is now being considered.

10% lower costs. Accumulated data on cryogenic vessels of 9% nickel steel suggest that minimum savings of 10% of the final erected costs can be expected from reductions in material, welding and fabricating costs alone, in comparison with non-ferrous metals. Economies due to higher strength are also possible. An allowable ASME working stress of up to 23,750 psi permits reduction in vessel weight with lower unit costs.

Acceptance of 9% nickel steel in the quenched and tempered, as-welded condition by code and regulatory bodies would make this steel even more attractive to designers and fabricators since the vessel would cost less to produce without stress-relieving and would be less expensive.

United States Steel Corporation • Columbia-Geneva Steel Division • National Tube Division • Tennessee Coal and Iron Division • United States Steel Supply Division • United States Steel Export Company

For maximum strength . . . toughness . . . safety

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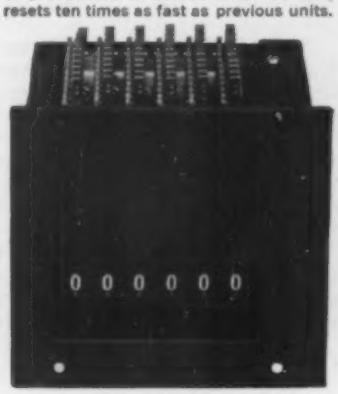
Series 1744 High-Speed Digital Readout Counter saves time and labor by eliminating manual counting and recording of production. It counts twice as fast, resets ten times as fast as previous units.



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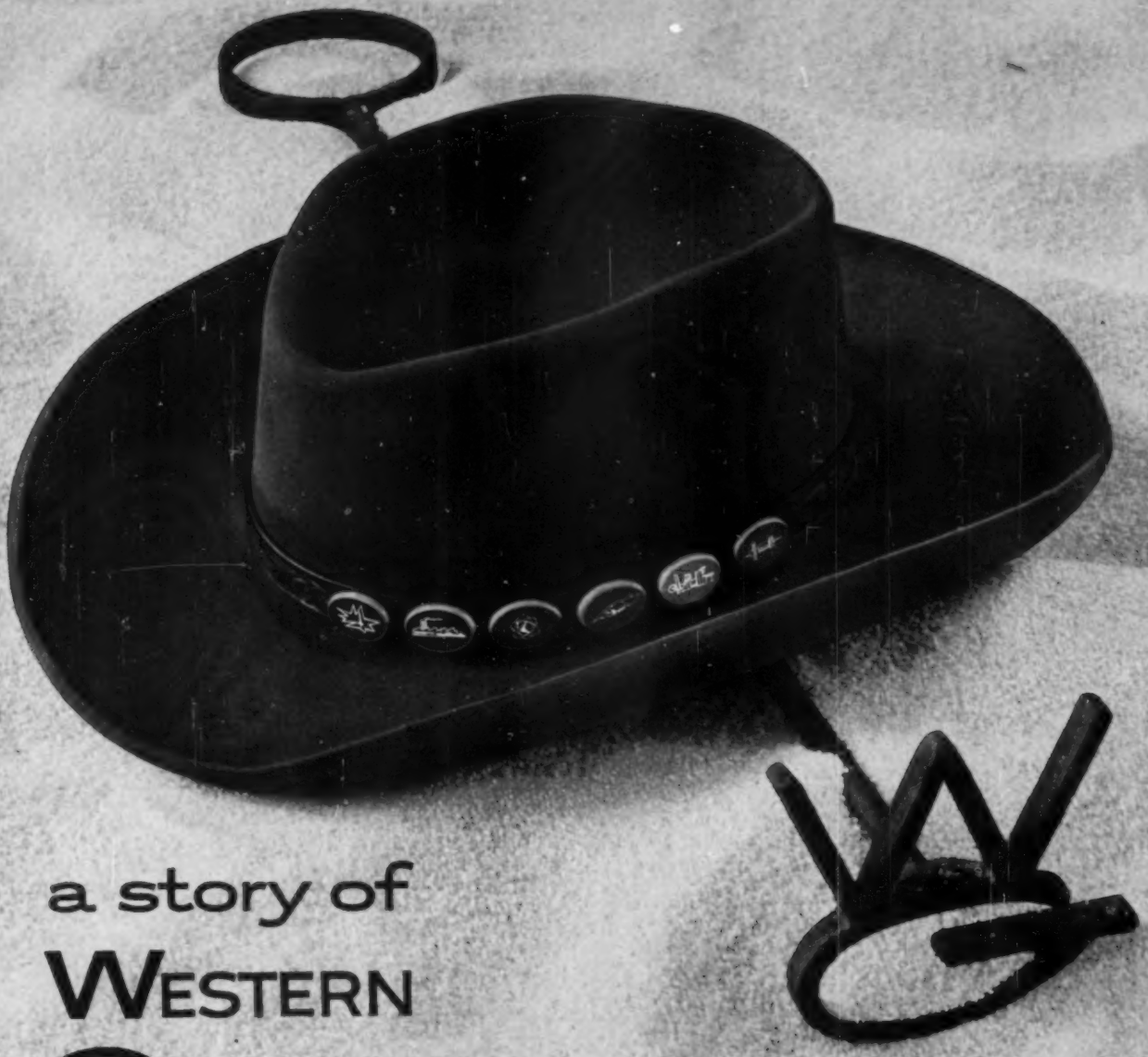

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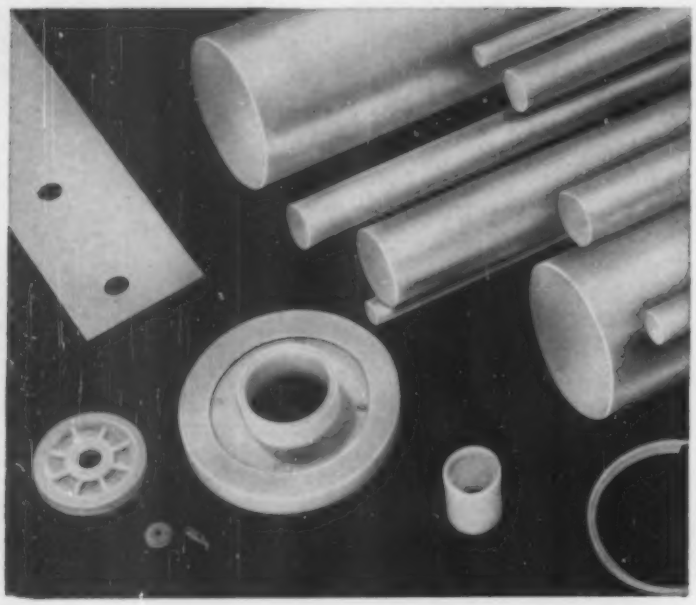
Circle 233 on Page 19

DELRIN

In Design Engineering



For ready cutting and machining, Style 8701 Delrin rod is available in standard diameters 1 ¼" to 3" standard lengths 4 and 8 feet.

NEW GARLOCK DELRIN now ready to help you achieve the extraordinary in product design.

This remarkable new material opens new horizons to you for creativity, product improvement and production economy. Just look at the unique combination of properties that make Garlock Delrin* superior in many ways to metals, as well as to many other widely-used plastics.

- Metal-like strength and rigidity—high dimensional stability and fatigue endurance.
- Resilience comparable to spring steel.
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- Low coefficient of friction.
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Best of all, Garlock Delrin retains these properties through a wide range of service conditions—temperature (−40°F to +250°F), humidity, and stress.

Add, too, important Garlock "know how" . . . years of experience in the fabrication of plastics, and unsurpassed molding facilities. Result: a combination that can produce intricate shapes and custom-designed parts never before possible. Garlock design engineers can now work directly with you in creating advanced components . . . parts that replace other materials and do the job better at lower cost.

Look to Garlock as the source for all your plastic needs—Teflon* (TFE and FEP), Nylon, Polychlorotrifluoroethylene (C.T.F.E.), and many other plastic materials. For complete information on what Garlock offers in the way of materials, facilities, and technical assistance, call your local Garlock representative at the nearest of our 26 sales offices and warehouses throughout the U.S. and Canada. Or, write for Catalog AD-177, Garlock Inc., Palmyra, N.Y.

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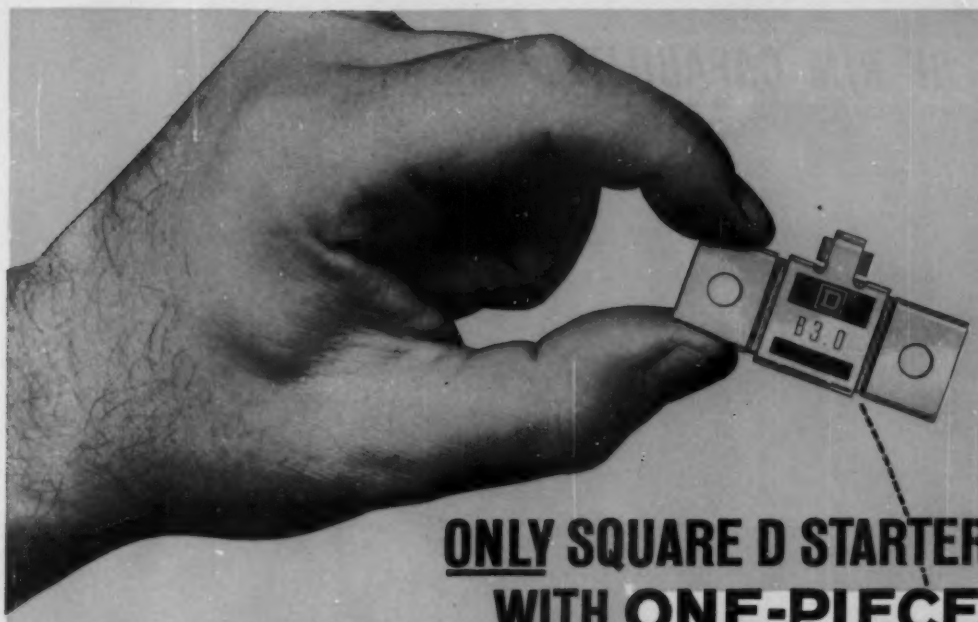
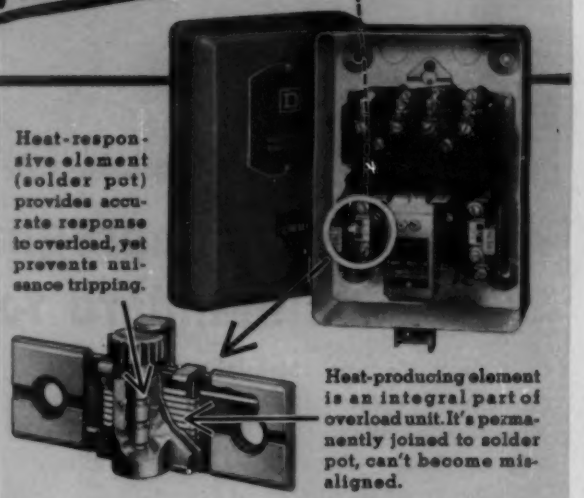


ONLY SQUARE D STARTERS WITH ONE-PIECE OVERLOAD RELAYS GIVE *Absolute* PROTECTION!

• Only Square D makes thermal overload relays with 1-piece construction—and only with 1-piece construction can you *know* you've installed the heater correctly. Square D 1-piece overload relays can be installed only one way. They are factory-assembled, individually tested and calibrated, completely tamper-proof. Repeated tripping will not affect accuracy.

You *pay* for overload protection—be sure you *get* it. Insist on Square D 1-piece overload relays for *absolute* protection.


Heat-responsive element (solder pot) provides accurate response to overload, yet prevents nuisance tripping.
Heat-producing element is an integral part of overload unit. It's permanently joined to solder pot, can't become misaligned.

D EXCLUSIVE—
1-piece Overload Relay
for *ABSOLUTE* Protection!

Mail coupon today for simple "jig-saw" demonstrator —see why only Square D gives absolute protection

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Please send me information on Square D magnetic starters, along with your simple 3-minute "jig-saw" demonstrator

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New Teflon-impregnated asbestos packing becomes standard for all Ohio Brass valves

Ohio Brass Company, Mansfield, Ohio, a leading producer of bronze valves for industry, wanted to standardize on a single packing for its entire line—asked Raybestos-Manhattan, Inc., to develop a suitable all-purpose packing.

Ohio Brass laid down three requirements: (1) it must be resilient and maintain gland torque; (2) must be effective in a wide range of applications; (3) must be priced right.

R/M packing engineers solved the problem with a unique combination of woven asbestos impregnated with Teflon.* Aside from eliminating the need for stem lubrication, this long-wearing packing is inert to the wide range of materials handled by O-B valves.

Whatever your needs in mechanical packings, gasket materials, and specialty products—call on R/M. Our engineering and production capabilities can effect an economical solution for your packing requirements. Send data on your application.

*Registered trademark for Du Pont fluorocarbon resins

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PACKINGS
PACKING DIVISION, PASSAIC, N.J.
MECHANICAL PACKINGS AND GASKET MATERIALS

EATON-RELIANCE
WILL INTRODUCE
AN EXCITING NEW
FASTENER
IN JANUARY
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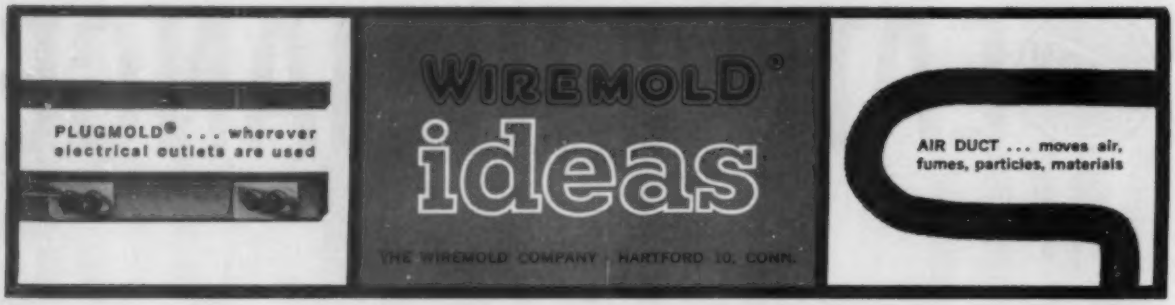
Circle 237 on Page 19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AIR DUCT . . . moves air, fumes, particles, materials

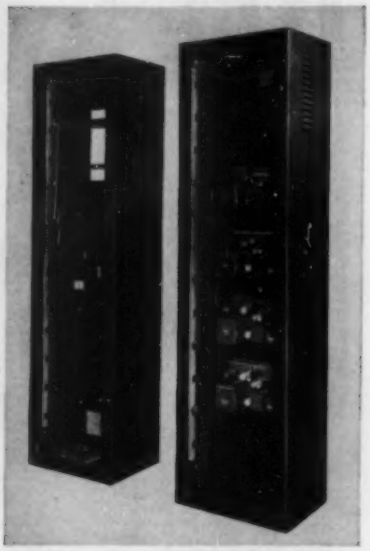
Versatile equipment studded with outlets

Plugmold built into electronic racks makes power accessible wherever it may be used

Typical of original equipment that needs available outlets, amplifier and power supply racks for large sound systems have added versatility with Plugmold. These multi-outlet assemblies allow almost unlimited possibilities for outlet arrangements.

Almost any arrangement of Plugmold can be accomplished: a single strip (far right), parallel runs (center), mounted horizontally, vertically, around corners, or in any fashion to match configurations of equipment. In both of these applications, factory wired sections were used, with duplex outlets spaced 6" on centers. Other standard outlet spacings, with duplex or grounding outlets, 2-wire or 3-wire, are also available. Other Plugmold types permit you to place many other kinds of devices in any position desired. For example, fuses, circuit breakers, multi-prong jacks, etc., can be installed in the raceway. Or, portable power strips can be made with provision for easy connect and disconnect.

At left, two rows of Plugmold provide outlets on electronic rack. At right, technicians' work benches have convenience outlets for equipment.



Plugmold outlet strips make a neat power source in back of amplifier and power supply racks.

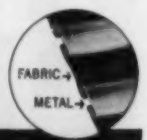
On your work bench too

Designers often use electrical/electronic equipment in their work. Plugmold is an ideal way to wire your work bench with all the outlets you need — the ultimate in convenient efficiency.

Standard Plugmold types are stocked by electrical wholesalers everywhere. Wiremold welcomes the chance to assist in developing special assemblies.

Flexible duct resists abrasion—

Even exhausts diamond dust



Wiremold's Type 8R duct combines the benefits of flexibility with rugged resistance to abrasion.

Designed to handle such abrasives as diamond dust, glass cuttings, wood chips, pulverized or granular materials, the duct is made of Nylon fabric coated with heavy, abrasion resistant neoprene. This fabric locks mechanically to a flat metal spiral (see cutaway) making the duct firm and rugged, yet completely flexible.

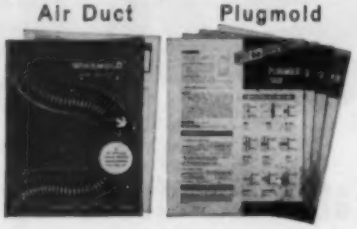
The duct can be assembled and secured in seconds. Fasten it to connector by securing 2 or 3 drill screws through the flat spiral and connector.

Six standard duct types cover a wide range of uses. Special shapes (e.g., square, oval) can also be furnished.

Exhaust duct on diamond dust collector. Cutaway shows duct's unique mechanical locking construction.

SEND FOR LITERATURE

Air Duct Plugmold



Circle 238 on Page 19A Circle 239 on Page 19A

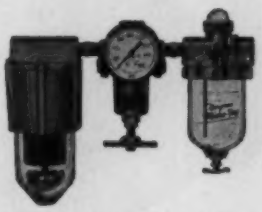
Norgren Lubro-Control Units

*A complete line of **visible oil feed** lubricator units for air-tools, air cylinders and other air-powered equipment*

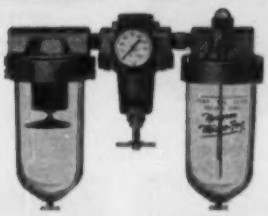
NORGREN Micro-Fog Combination Units

Easily adjustable for the exact amount of lubrication required

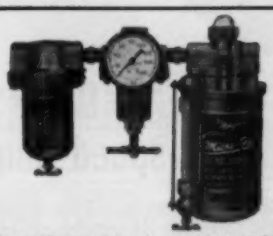
Transparent bowl filter; pressure regulator with gauge; transparent bowl Micro-Fog Lubricator. ⅛" pipe size. ½ oz. lubricator capacity. Small, compact unit for use where space is tight.



Transparent bowl automatic-drain filter; regulator with gauge; transparent bowl, Micro-Fog Lubricator. ¼", ⅜", ½", ¾", 1" pipe sizes. ½ pt. lubricator capacity.



Transparent bowl manual-drain filter; pressure regulator with gauge; transparent bowl, Micro-Fog Lubricator. ¼", ⅜", ½", ¾", 1", pipe sizes. 2½ pts. lubricator capacity.

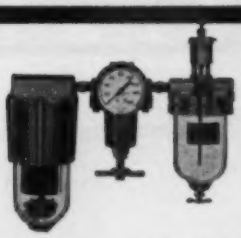


Replaceable metal bowl manual-drain filter; pressure regulator with gauge; replaceable metal bowl, Micro-Fog Lubricator with constant oil level. ¼", ⅜", ½", ¾", 1" pipe sizes. 1 qt. lubricator capacity.

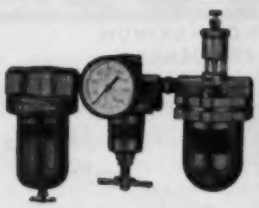
Compact cabinet unit for air operated machine tool applications. Provides filtered air, accurate regulation and control of oil delivery, visible, adjustable oil feed. ½" pipe size. 10 oz. oil capacity.

NORGREN Oil-Fog Combination Units

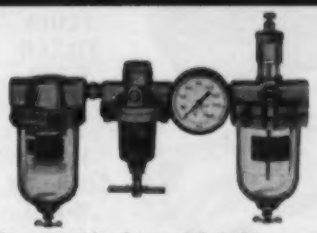
Efficient, effective lubrication of air-powered equipment.



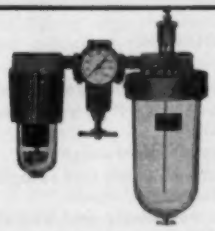
Transparent bowl automatic-drain filter; regulator with gauge; transparent bowl lubricator. ¼", ⅜", ½", ¾", 1" pipe sizes. ½ pt. lubricator capacity.



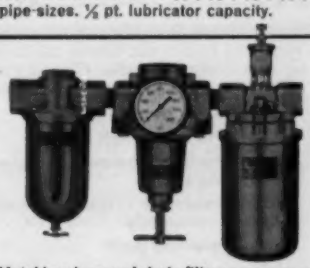
Replaceable metal bowl manual-drain filter; pressure regulator with gauge; replaceable metal bowl lubricator. ¼", ⅜", ½", ¾", 1" pipe sizes. ½ pt. lubricator capacity.



Transparent bowl manual-drain filter; pressure regulator with gauge on tee; transparent bowl lubricator. ¼", ⅜", ½", ¾", 1" pipe sizes. ½ pt. lubricator capacity.



Transparent bowl automatic-drain filter; pressure regulator with gauge; transparent bowl lubricator. ¼", ⅜", ½", ¾", 1" pipe sizes. 1½ qt. lubricator capacity.



Metal bowl manual-drain filter; pressure regulator with gauge; replaceable, metal bowl lubricator. ¾", 1" pipe sizes. 1 qt. lubricator capacity.

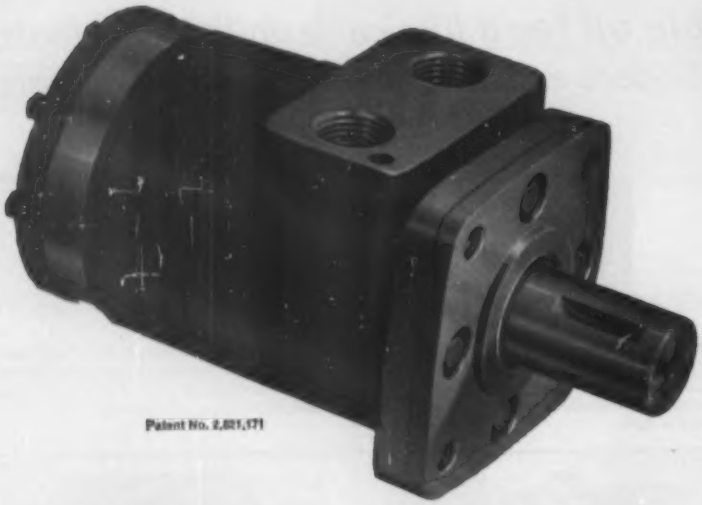
Shown here are a few models from Norgren's complete line of air filters, pressure regulators and lubricator units. For full information, call your nearby Norgren representative listed in your phone directory, or write for descriptive literature.

C. A. NORGREN CO.

3442 SOUTH ELATI STREET • ENGLEWOOD, COLORADO

Circle 240 on Page 19

HIGH TORQUE at SLOW SPEED

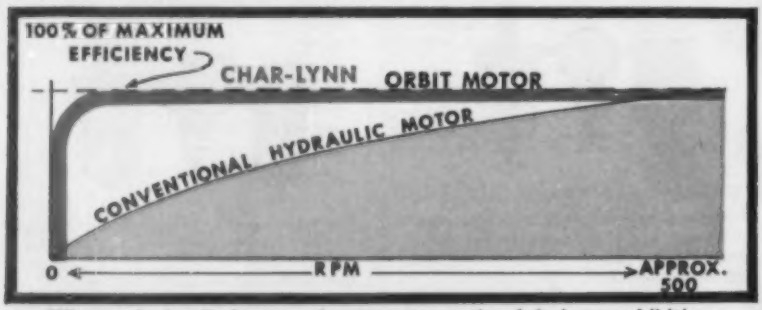


Patent No. 2,821,171

New Char-Lynn Hydraulic ORBIT MOTORS® deliver Full Torque regardless of speed range

It's Here—A NEW concept in fluid power mechanics has brought about the development of a totally new fluid motor—A *High Torque—Low Speed* motor.

These motors open up complete new areas for design, never before possible. They offer a practical and economical hydraulic solution to the age-old problem of providing High Torque at Low Speeds for constant and variable speed drives—hydrostatic transmissions and remote controls *without* bulky, costly mechanical drives and gear reducers.



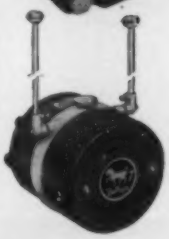
Whereas hydraulic losses make some conventional designs prohibitive at the lower speeds, Char-Lynn ORBIT MOTORS maintain high efficiency over the complete operational range.

- Speeds from 0—800 RPM
- Torques to 3300 inch lbs.
- Starting torque substantially equal to running torque
- Fully reversible — instantaneous starting—stopping
- Only 3 moving parts
- 4 types of mountings available
- 3 port sizes—7 power element selections
- Compact—lightweight
- Eliminates costly and complicated power transmissions
- High volumetric and overall efficiency

complete your HYDRAULIC CIRCUITS with Char-Lynn COMPONENTS

HOLDKONTROL VALVE V-960

HORSEPOWER PUMP 400

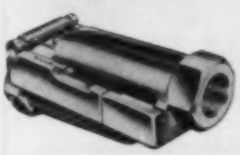


HI-LO POWER PAC PUMP P-600

STROKONTROL CYLINDER C-133

HORSEPOWER CYLINDER C-102

HYDRAULIC FLUID FILTER F-240



HOSE COUPLER H-730

For complete details write **Dept. HM Char-Lynn Company** • **2843-26th Avenue South, Minneapolis, Minnesota**

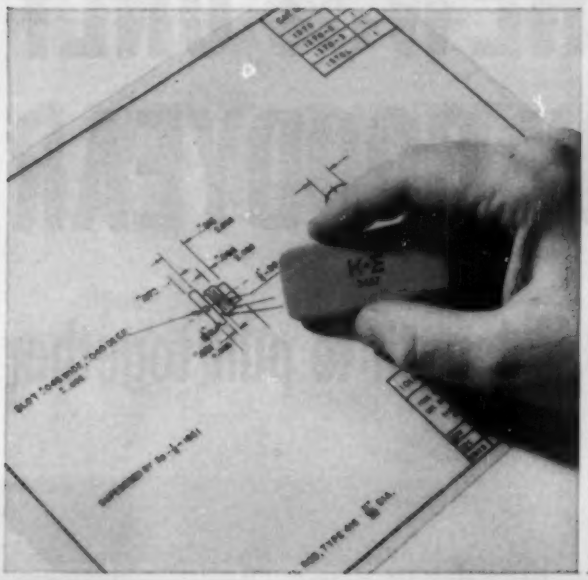
Char-Lynn

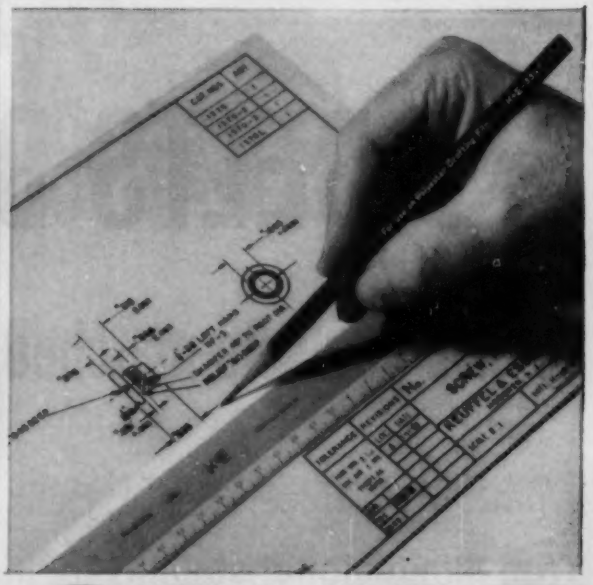
HYDRAULIC HORSEPOWER PRODUCTS

Please direct inquiries to advertiser, mentioning MACHINE DESIGN

For engineering "duplicate originals"...

Use the Polyester Films you can work on





PHOTACT® by K&E

To perfect an engineering drawing requires constant revision, addition and change. Yet most photographic polyester films on the market today reflect a disregard for this fact by combining photo emulsion and drafting surface in a single surface layer. If you mechanically erase image lines on these films the drafting surface is removed, and pencil or ink will no longer take on the film surface. The only alternative is to use eradicators, a time-wasting, nerve-frazzling process.

Only PHOTACT Polyester Films have an additional drafting surface *beneath* the photo emulsion. No eradicators needed. Repeated erasures easily made. In short, the answer to a draftsman's prayers.

Erase cleanly. Using a mildly abrasive Van Dyke eraser (K&E 3457) image lines can be whisked off completely in nothing flat. Even tight, detail lines which are too tightly arranged for eradicators can be removed with a stick-pencil eraser.

Re-draw Repeatedly. The matchless K&E engineered drafting surface won't lose its "take" or erasing qualities even after many revisions, one on top of the other. To apply lines of ink-like density, we recommend one of a wide range of new Ruwe plastic-graphite pencils or drawing leads.

Get Perfect Duplicates and Prints. The PHOTACT emulsion yields solid blacks, true to the original drawing with no fill-in or drop-out. Wide exposure latitude almost guarantees that the first exposure is the right one. Prints are developed in regular *paper* developer; high-priced, short-lived litho developers are not necessary.

PHOTACT Polyester Films are available in three basic types—Contact (409) for same-size exposure; Direct Positive (411) for same-size positives from transparent originals; Projection (419) for prints from microfilm negatives.

FREE... New PHOTACT Selection Guide. Just off the press, K&E has available a new guide to the use and selection of PHOTACT materials. It's crammed full of time-saving tips, quick-reference charts and processing hints. Your copy is free for the asking. See your local K&E dealer or fill out and mail the coupon below.

KEUFFEL & ESSER CO.

NEW YORK • HOBOKEN, N. J. • PHILADELPHIA • DETROIT
CHICAGO • MILWAUKEE • ST. LOUIS • DALLAS
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KEUFFEL & ESSER CO., Dept. MD-12 Hoboken, N. J.

Gentlemen:

Please send me your new PHOTACT Selection Guide.

Name & Title: _____

Address: _____

4257-A

GOODYEAR

NEWS! ONLY V-BELTS BY GOODYEAR

to give you sets matched in length to pull together

What's more, Green Seal V-Belts give you—

True dimensional stability for the life of the belt—built in through the use of shrink- and stretch-resistant 3-T Process Cord or airplane-type steel cable.

Mildew-inhibited construction for protection in damp operating conditions.

Widest selection from the most complete V-belt line anywhere.

Ready availability from distributor stocks in every part of the country.

Technical assistance whenever it's needed from a qualified expert, the G.T.M.—Goodyear Technical Man.

For the best buy in V-belts call your Goodyear Distributor. Or write Goodyear, Industrial Products Division, Akron 16, Ohio.

Lots of good things come from GOODYEAR

GREEN ✿ SEAL ARE CODED TO 1/32"...

perfectly for longer, more trouble-free service

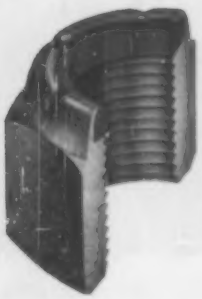
LENGTH-CODING GREEN SEAL V-BELTS TO 1/32"—NOT JUST 1/10", LIKE MOST BELTS—takes this ultra-precision machine. Only Goodyear has this type equipment, which is set by means of fine tolerance steel templates to insure accuracy. Machine readings are in the actual code numbers used to eliminate errors.

Green Seal—T. M. The Goodyear Tire & Rubber Company, Akron, Ohio

YEAR INDUSTRIAL PRODUCTS

When frequent adjustment or dis-assembly is anticipated

USE NYLON INSERT ELASTIC STOP® NUTS



Extended re-useability is built into every standard Elastic Stop nut. The tough nylon locking collar does the trick.

It grips entering bolt threads with a plastic-smooth perfect fit that dampens impact loads, absolutely resists vibration, yet never galls or damages bolt threads. The nut may be "stopped" at any place on the bolt, whether seated or not, for precision adjustment. When the nut is wrenched off for routine maintenance, the nylon collar, due to its elastic recovery, tends to resume its original shape. Thus upon re-installation it grips the bolt threads as effectively as on the original installation. And this on-off cycle can be repeated over 50 times on any bolt of standard quality without loss of holding power.

The nylon locking collar can also be used to seal off liquid seepage along the bolt threads and to prevent moisture from entering the load carrying areas. It is inert to oils, gasolines, salt atmospheres and common acids.

Consider the economy to you and your customers of this kind of fastener performance. Let us prove it to you. Ask for free test samples . . . or a copy of Recommended Test Procedures for Determining Locknut Re-Useability. Write: Elastic Stop Nut Corporation of America, Dept. S50-124, Vauxhall Road, Union, New Jersey.

for the ring **O** *reliability*

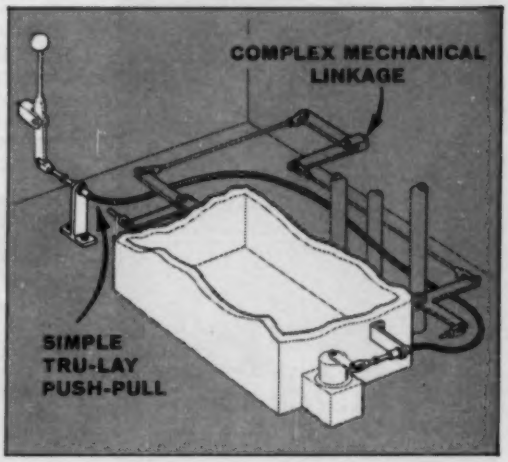
ELASTIC STOP NUT CORPORATION OF AMERICA

Circle 243 on Page 19

TRU-LAY *PUSH*-PULL CONTROLS PROVIDE

Dependable Economical Easy-to-Use REMOTE CONTROL

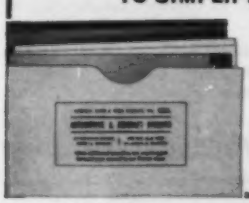
• If your products involve remote control—electrical, hydraulic, pneumatic or direct—TRU-LAY PUSH-PULL FLEXIBLE CONTROLS can help solve your design problems. They provide positive remote control over long or short distances —up to 150 feet from the control point. Because they operate while flexing, they can snake around obstructions. They will not buckle. They're factory-lubricated for life, unaffected by temperature extremes. They are ruggedly constructed, easily installed and operated, sealed against dirt and moisture, and will handle jobs with as much as 1,000 lbs. input. PUSH-PULL CONTROLS are simple, have but one moving part, are noiseless, and give a lifetime of accuracy. Mechanical linkages, on the other hand, are complex. Unlike PUSH-PULL CONTROLS, they are made of many parts, wear at many points, and produce increased backlash, lost accuracy, and vibration rattles.



CABLE SIZES AVAILABLE

Control Dimension	Minimum Recommended Radius in Inches	Maximum Input Load in Pounds (Dependent on Travel)
3/32"	2	30
1/8"	3	65–125
3/16"	5	115–175
1/4"	6	300–600
5/16"	8	700–1,000

PUSH-PULL DATA FILE SHOWS HOW TO SIMPLIFY, IMPROVE DESIGN



• Write for your PUSH-PULL Data File. It contains a complete set of engineering bulletins which describe in detail the operation of PUSH-PULL CONTROLS, their applications, features and advantages.

Operating Heads to Fit Your Design
for loads up to 125 lbs.

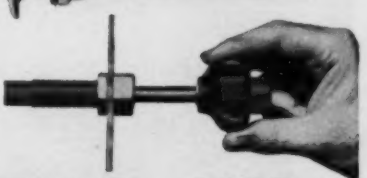
Heavy Duty • For rugged duty, but where operation must be smooth and accurate. Meets all requirements for dependability and life.

Light Duty • Smooth, accurate, dependable performance at low cost. Your choice of several types of knobs.

Selective Friction • Amount of friction can be changed to meet individual requirements. Friction constant at any setting.

Position Lock • A slight turn of the T-type handle locks the control in any position. Two sizes for light and heavy-duty applications.

Micro Control • Push or pull the knob for instantaneous response, then rotate knob for vernier adjustment.



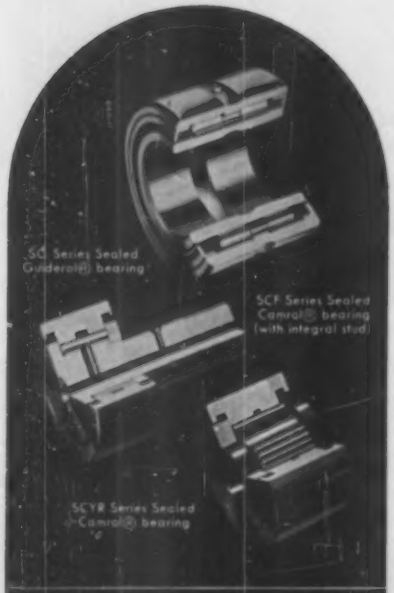
PUSH-PULL CONTROLS

Automotive and Aircraft Division • American Chain & Cable Company, Inc.

601-A Stephenson Bldg., Detroit 2

6800-A East Acco Street, Los Angeles 22 • 929-A Connecticut Ave., Bridgeport 2, Conn.

ACCO


SC Series Sealed Guiderol® bearing
SCF Series Sealed Camrol® bearing (with integral stud)
SCYR Series Sealed Camrol® bearing

Seals keep lubrication in, abrasives out in SCF CAMROL lapping machine use

Sealed SCF Series CAMROL bearings position conditioning rings into which work pieces are placed in Crane Packing Company LAPMASTER lapping machines. The bearings roll in a loose abrasive and oil environment. The user reports longer life with less maintenance than the ball bearings formerly used.

McGILL® prelubricated and sealed bearings

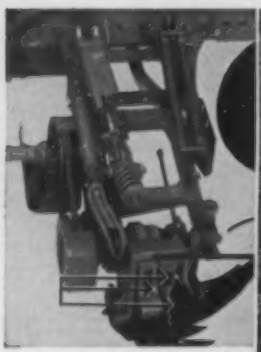
insure product performance

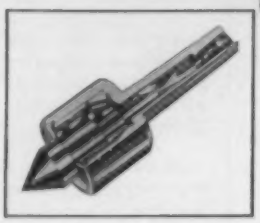
Contamination and loss of lubricant cut bearing life drastically. That's why more and more manufacturers are specifying McGill sealed bearings. Integral seals extend bearing life and keep equipment in service even under adverse field conditions.

You can expect full rated life from McGill sealed bearings in applications involving exposure to dirt and grit or contaminants which tend to dilute the lubricant. They're also ideal where re-lubrication is impractical or difficult.

McGill sealed GUIDEROL and sealed CAMROL bearings eliminate the need for expensive auxiliary seals. Each bearing is complete and they are easy and economical to apply.

Sealed CAMROL bearings are available in roller diameters up to 4", with or without integral stud. Also available with extra heavy stud. Sealed GUIDEROL bearings are available in shaft sizes from 5/8".





"Live Center" application

Motor Tool Manufacturing Co. reports that the sealed GUIDEROL bearings used in their new heavy duty live centers will carry heavier radial loads for their diameters than any bearing they know of. They also state that performance difficulties run less than 1% in spite of severe operating conditions.

Sealed GUIDEROL and Sealed CAMROL bearings used by JOHN DEERE

McGill Sealed GUIDEROL bearings at each end of the connecting rods and at the end of the swing-arm sickle drive of John Deere No. 10 side-mounted mowers reduce friction and assure efficient field operation. The sealed GUIDEROL bearings in their exposed positions are indicated in the photo above at left. The swing-arm sickle drive bearing outlasts three bronze bushings in the application. Oscillating loads of approximately 700 pounds are encountered in this position. The connecting rod bearings are subjected to reciprocating loads of 1600 pounds.

Deere also uses sealed SCYR series CAMROL bearings in plunger head guider rollers in their 323-W balers.

engineered electrical products

McGILL®

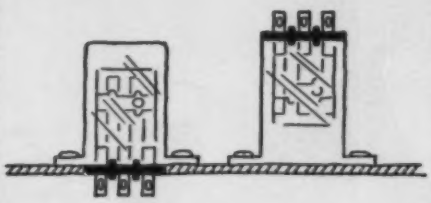
precision needle roller bearings

Send for free copy of McGill Bearing Catalog No. 68

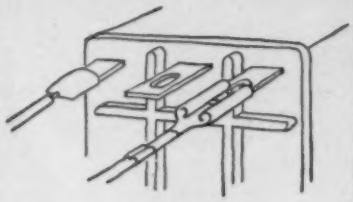
MULTIROL®-GUIDEROL®-CAMROL®-CAGEROL®

McGILL MANUFACTURING CO., INC., Bearing Division
200 N. Lafayette Street, Valparaiso, Indiana

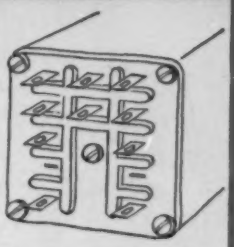
FRESH IDEAS IN RELAYS...



CHOICE of below-chassis or above-chassis connecting in plastic enclosures.



MULTI-USE terminals allow soldering, insertion in printed circuit board, and use of AMP Style 110 push-on terminals.



ALL TERMINALS on *one* panel... permits insertion in printed circuit board.

SPECIFICATIONS

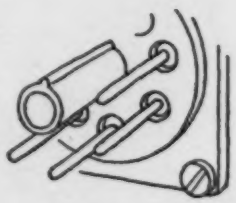
CONTACTS: *Integral with terminals;* up to 3PDT; 5 amp, 115 VAC or 32 VDC. Stationary contacts, fine silver inlay material; movable, solid fine silver.

COILS: Up to 230 VAC at 60 cps or 115 VDC.

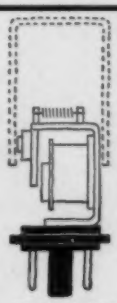
ENCLOSURES: Clear plastic.

TERMINAL PANELS: Barrier type or octal plug.

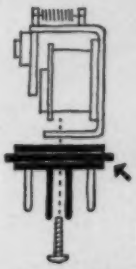
LATCHING RELAY: Available enclosed in clear plastic with plug-in mounting; or unenclosed.



OCTAL PLUG relays up to DPDT have recessed pin bases . . . meet UL spacing requirements to 150 V.



ALL ENCLOSED relays mount solidly on base . . . *not* on covers.



INTEGRAL plug-in base up to DPDT avoids wiring between contact terminals and pins.

OHMITE'S New "GR" Series

Stocked for Immediate Delivery From Distributors or Factory...

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OHMITE MANUFACTURING COMPANY
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Rheostats • Power Resistors
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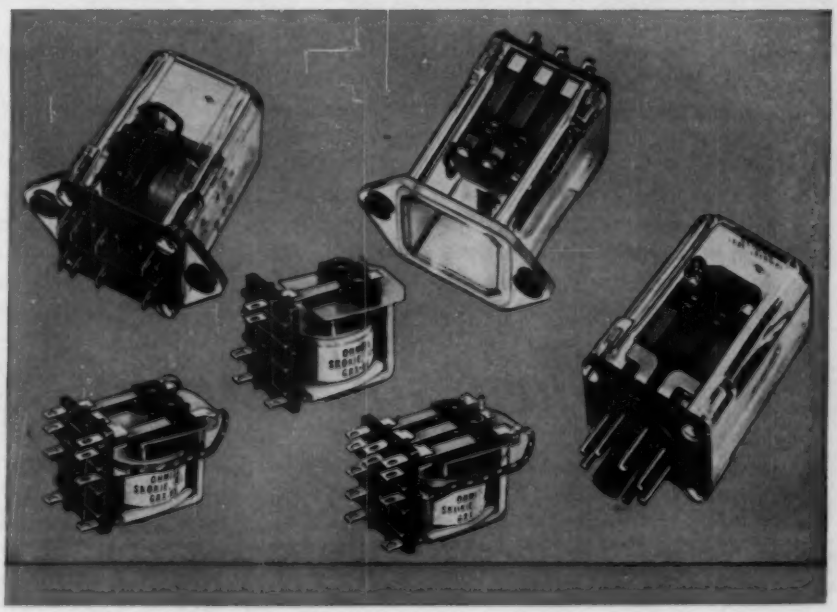

Circle 246 on Page 19

yours free, if you can use it

If you are one of the relatively few, highly skilled engineers in America today whose job requires a knowledge of the mysterious, highly specialized alloys used in magnetic, electronic and electrical applications, you'll want this new 64-page booklet.

In it are the two kinds of vital information about these alloys electronic designers need most today—what they will do and where you can get them, fast.

The technical data and case histories for this booklet were compiled by the metallurgical staff of The Carpenter Steel Company. They're giving you, free, the benefits of their own wide experience in producing the largest selection of these highly specialized alloys ever available from any one steelmaker.

In fact, there isn't a single Carpenter alloy mentioned in this booklet that you can't get in quantity right now.

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Get your free copy of this booklet—and get in touch with the men who wrote it—by sending your request today on your company letterhead. The Carpenter Steel Company, 120 W. Bern Street, Reading, Pa.

Carpenter steel

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Steel

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Export Dept., Port Washington, N.Y.—"CARSTEELCO"
Alloy Tube Division, Union, N. J.
Webb Wire Division, North Brunswick, N. J.
Carpenter Steel of New England, Inc., Bridgeport, Conn.

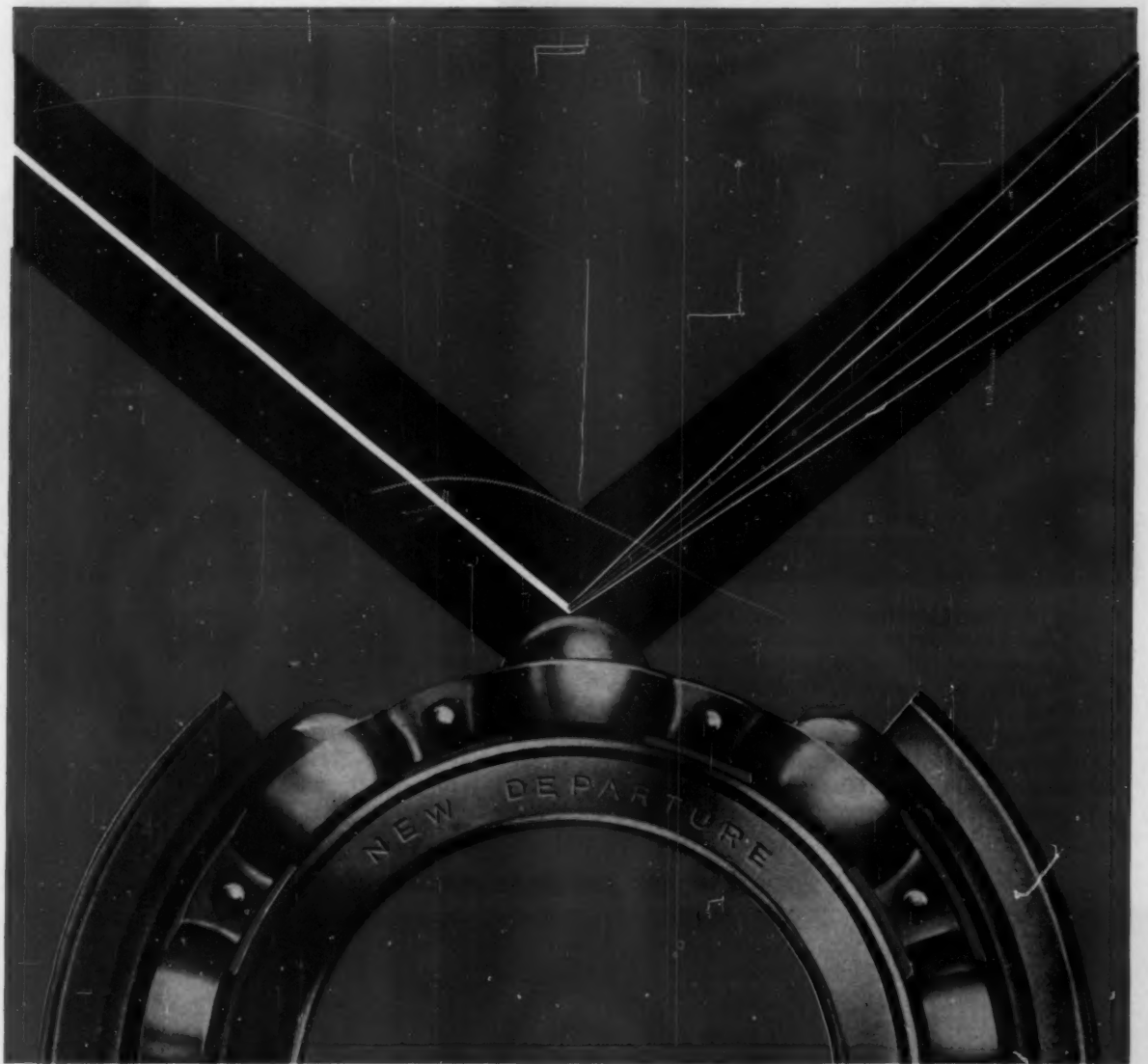
Circle 247 on Page 19

NONDESTRUCTIVE INSPECTION DEVICES SEEK OUT MINUTE FLAWS —help New Departure make better bearings!

One such device is *the N/D Ball Scanner*. As eagle-eyed instruments, they subject balls coming down the lines to the closest scrutiny. With unfailing consistency, they automatically reject balls having the minutest traces of rust, pits, grind marks, blemishes, and other faults, normally undetected by visual inspection. Result—balls made by New Departure are more defect-free than ever before. Bearings assembled with these balls and used in your products deliver better performance with greater reliability.

Development of nondestructive inspection devices has long been one of New Departure's principal R & D efforts. The Ball Scanner is just one of the existing devices that are already bringing you higher quality and more reliable bearings. Others are still under "wraps," but are destined to bring you even better bearings in the near future.

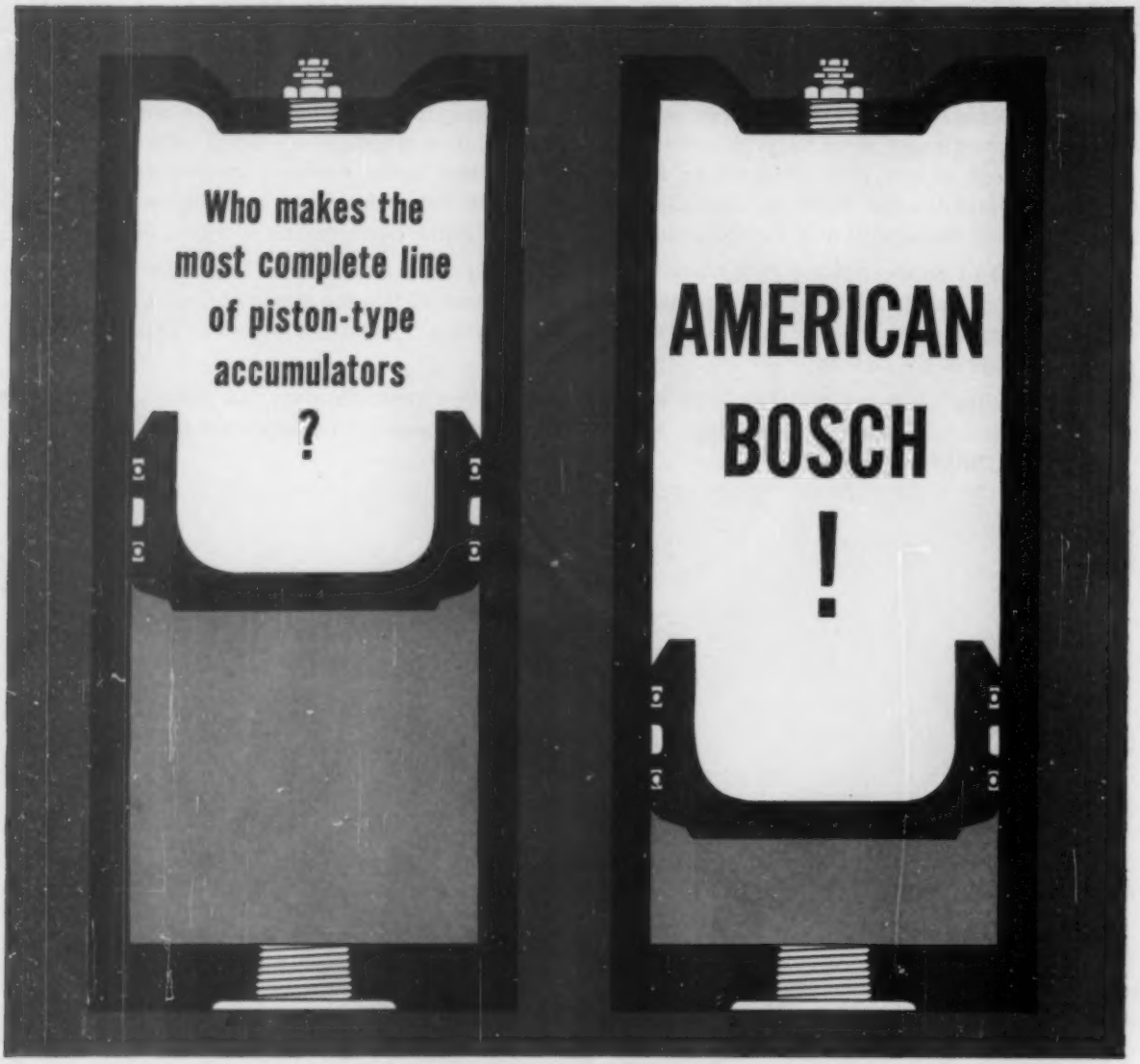
The advantages of these ball bearings are available to you now. Contact the New Departure Sales Engineer in your area. New Departure, Division of General Motors Corporation, Bristol, Connecticut.



NEW DEPARTURE

BALL BEARINGS · PROVED RELIABILITY YOU CAN BUILD AROUND

Circle 248 on Page 19



Proved for performance and reliability, American Bosch piston-type accumulators provide a powerful work-force for hundreds of industrial, marine, and mobile applications. Sizes range from less than a quarter pint to twenty gallons. Models are available for a variety of pressures in both steel and aluminum—in many diameters, lengths, and capacities. Custom-made models built to specifications.

American Bosch accumulators are manufactured to meet the most rigid requirements. Various types conform to MIL-A-5498C, ASME, JIC and U. S. Coast Guard specifications. When you specify accumulators for hydraulic systems, call for American Bosch. Complete information is contained in a new folder AC 110-02-2 . . . write for a copy and the name of your nearest distributor today.

8540

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AMERICAN BOSCH ARMA CORPORATION

Commercial Sales Division • Springfield 7, Massachusetts

ACCUMULATORS FOR INDUSTRIAL, MARINE, AND MOBILE APPLICATIONS

Circle 249 on Page 19

Look to

FAFNIR

for leadership in ball bearings

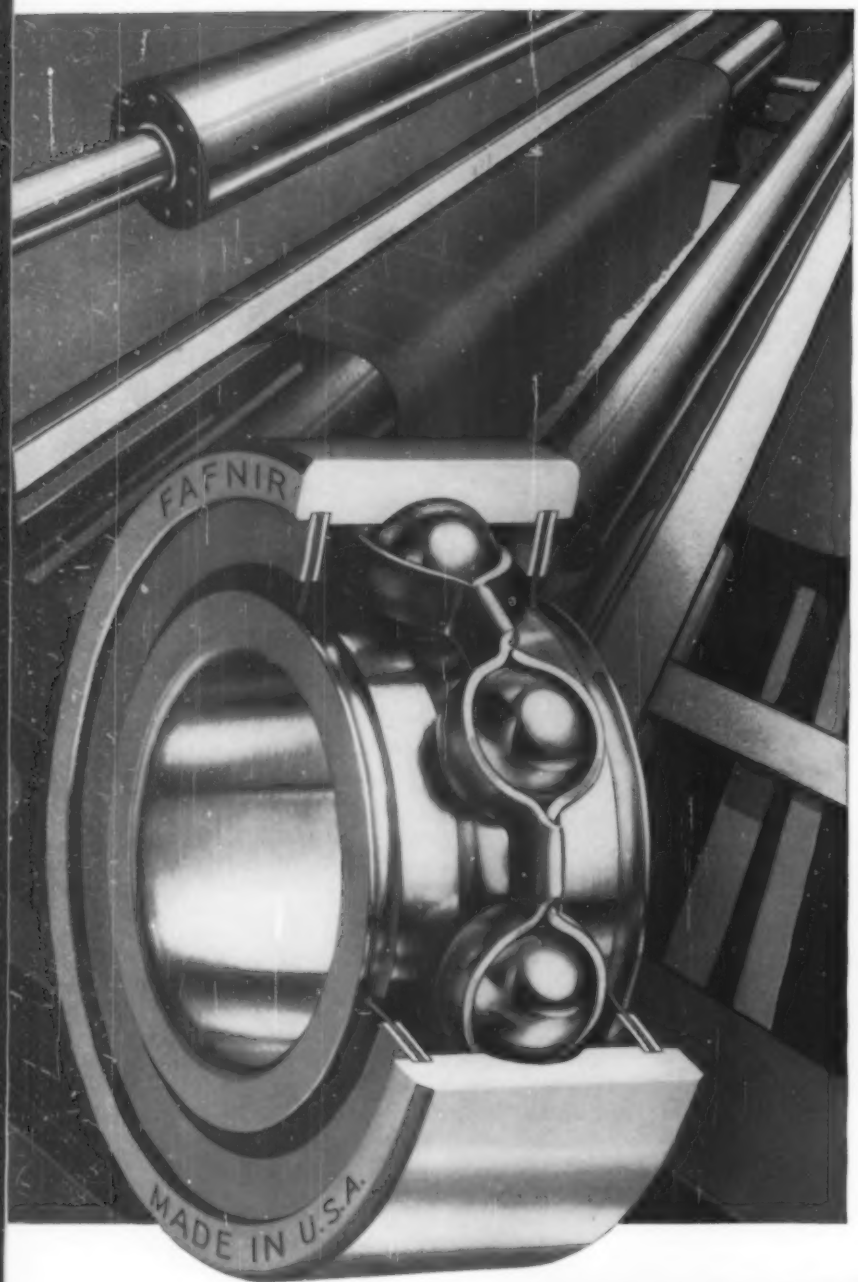
Rubber-cushioned ball bearings that run super-quiet

Modern air conditioning keeps a home comfortable... and does it *quietly*. One reason: Fafnir Super-Quiet Ball Bearings. Developed by Fafnir, these bearings are cushioned in current-conducting rubber to absorb noise. The bearings themselves are specially honed for silent service. Look to *Fafnir* for leadership in ball bearings. The Fafnir Bearing Company, New Britain, Connecticut.

50 YEARS OF EXPERIENCE
IN THE MANUFACTURE OF
BALL BEARINGS

FAFNIR
BALL BEARINGS

Look to **FAFNIR**

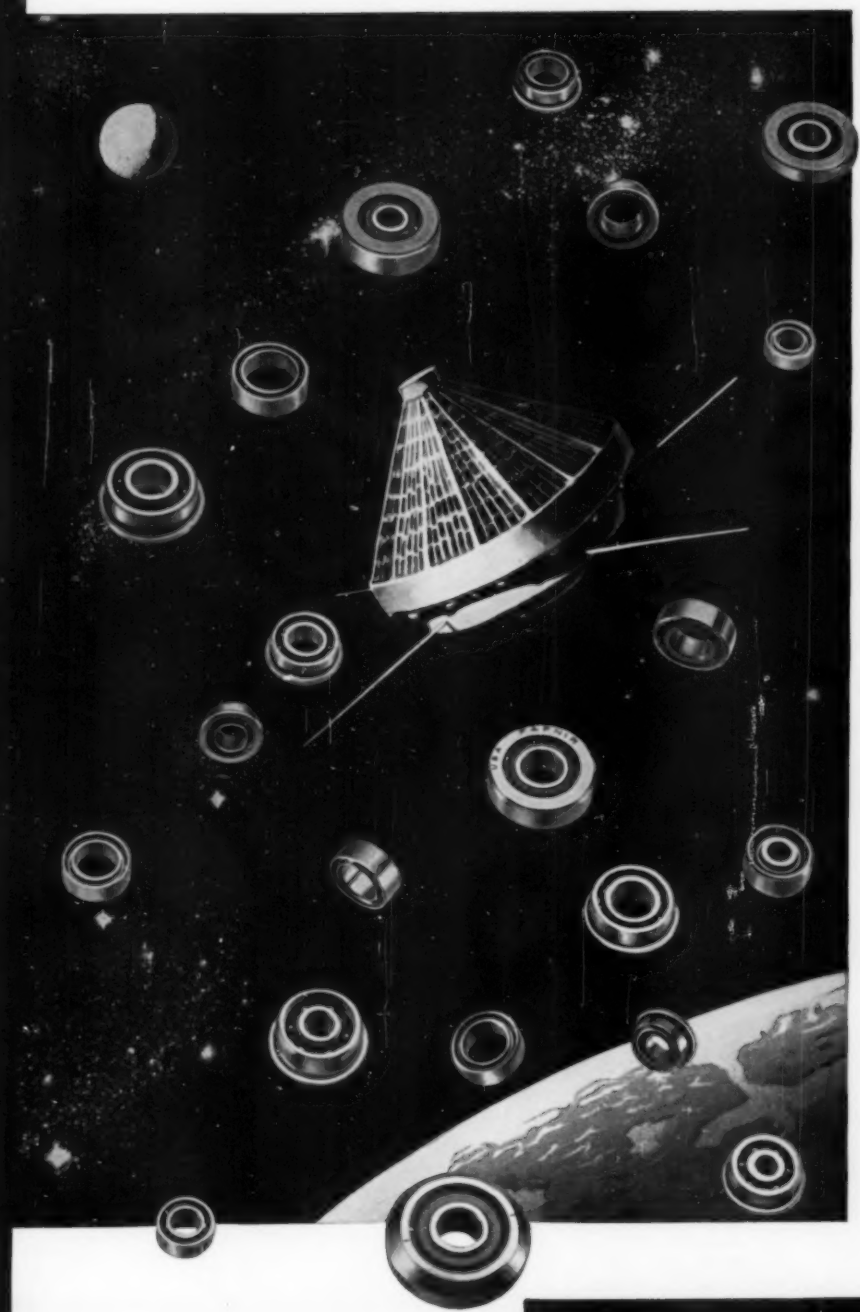


for stainless steel ball bearings that resist corrosion

Textile finishing can "finish off" bearings . . . fast! To control the corrosive effects of moisture, fumes, dyes, and acids, Fafnir developed stainless steel ball bearings with seals designed for extremely severe service. These bearings are used today in a wide variety of textile wet processing equipment. Look to *Fafnir* for leadership in ball bearings. The Fafnir Bearing Company, New Britain, Connecticut.

FAFNIR
BALL BEARINGS

Look to **FAFNIR**

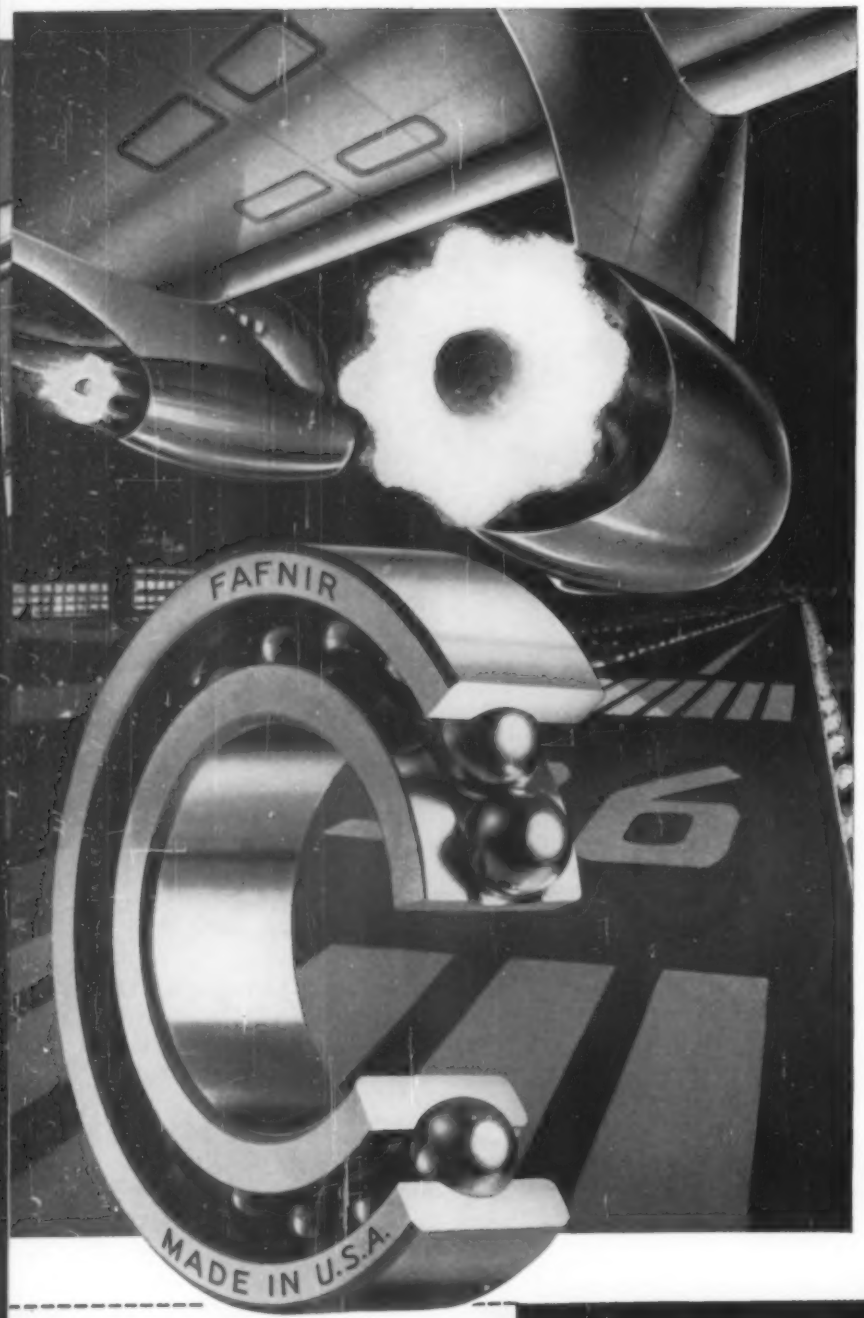


for miniature ball bearings of extra-clean vacuum-melt steel

Seconds after countdown, a microscopic pit in a miniature bearing could ground the most carefully planned space shot. To eliminate pits and other imperfections, Fafnir helped pioneer miniature ball bearings of vacuum-melt stainless steel. This "extra-clean" steel is completely free of impurities, and makes for flawless bearing performance. Look to *Fafnir* for leadership in ball bearings. The Fafnir Bearing Company, New Britain, Connecticut.

FAFNIR
BALL BEARINGS

Look to **FAFNIR**



for cobalt-base alloy ball bearings that withstand high temperatures

Air bled from jet engines comes through *hot*. And the pressure is tremendous. For ball bearings that can stand these jet-hot heats and jet-high pressures, Fafnir turned to cobalt-base alloys. These "exotic" Fafnir bearings are ideally suited for turbo-drive butterfly valves and similar high temperature, high load applications. Look to *Fafnir* for leadership in ball bearings. The Fafnir Bearing Company, New Britain, Connecticut.

MADE IN U. S. A.
This stamp on a Fafnir Ball Bearing means finest quality and workmanship . . . dependable supply . . . competent engineering help . . . and **responsibility** in meeting your bearing needs. It's worth bearing in mind.

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NEW BRITAIN, CONNECTICUT

Our ball bearing problem is ☐ Noise ☐ Corrosion
☐ Miniaturization ☐ Heat. Other:.....
We'd like to talk it over with you and get Fafnir's ideas.

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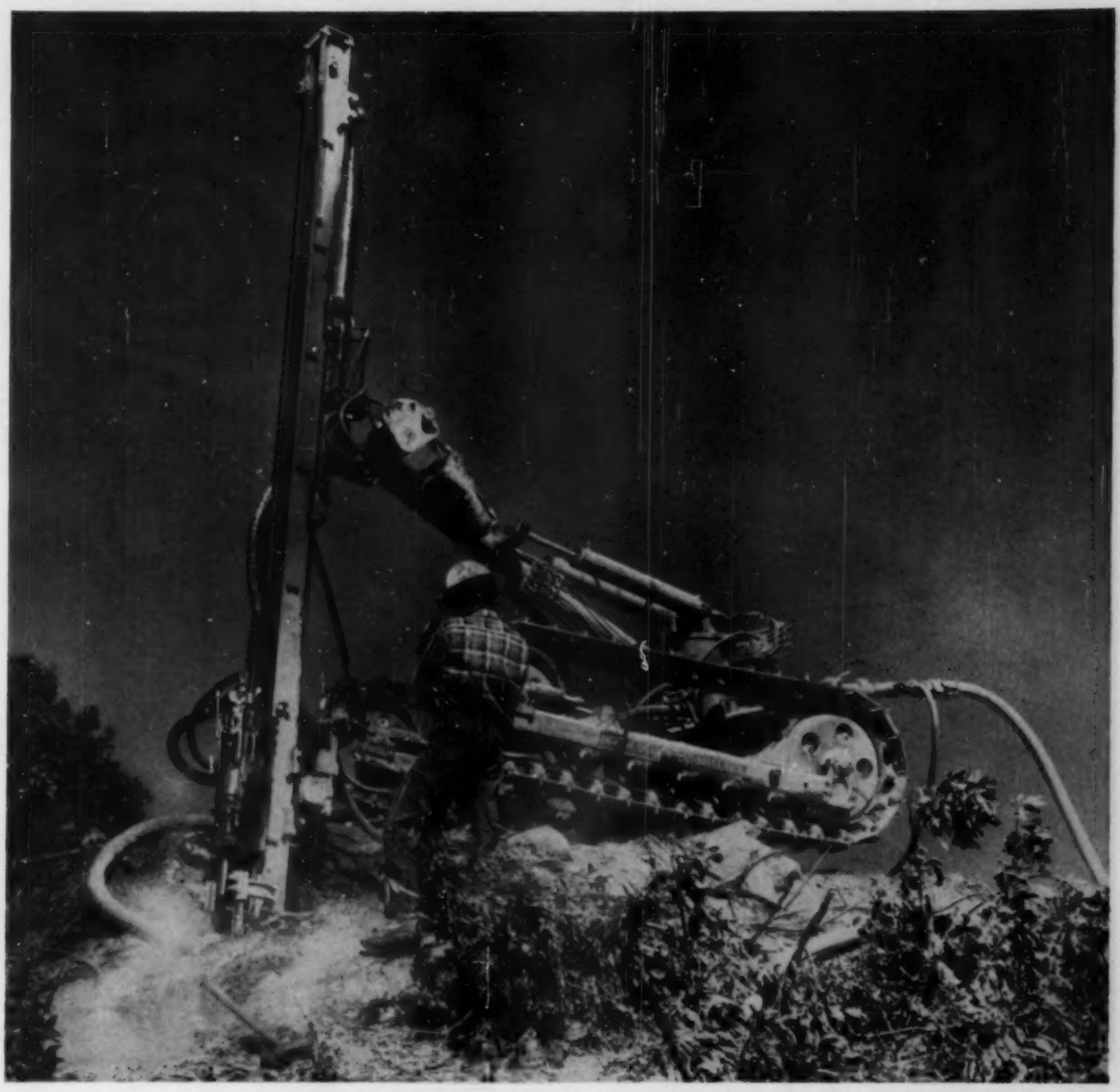
FAFNIR
BALL BEARINGS



1,000,000 blows a day into solid rock

Nickel alloy carburizing steels sustain powerful punch of heavy-duty drill.

Every working day this G-900 Tracdril* hammers its bit deep into solid rock. Connecting the drill motor and the bit is a string of steel which must take the torturous impact of more than 25 blows per second without failing. To meet this stern requirement Chicago Pneumatic engineers specify nickel alloy carburizing steels for the most critical parts.

In the chuck end of the drill, where the punishment is most severe, carburized and hardened AISI 3312 (3.5% Ni, 1.5% Cr) is used. Parts made of AISI 3312 withstand severe compressive loading and wear resistance, because under heat-treatment they develop a surface hardness of 60 Rc min. coupled with a core hardness of 35-40 Rc.

In the drill feed motor rotor and the rifle bar and striking bar of the drill AISI 4620 (1.8% Ni), provides excellent strength and toughness. To take high shock loads and heavy wear, these parts are carburized and hardened for a tough, impact-resistant core beneath a hard case. AISI 4620 provides minimum distortion during heat-treatment and at a hardness of 60 Rc can handle compressive loads of 200,000 psi.

AISI 3312 and 4620 are just two of many nickel alloy steels that handle rugged jobs in all sorts of heavy-duty equipment. They last longer, perform better, and can be fabricated at practical cost. If you'd like help with your problems in the selection of alloys, simply write to Inco describing them.

*T.M. Chicago Pneumatic Tool Co.

THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street INCO New York 5, N. Y.

INCO NICKEL

MAKES STEEL PERFORM BETTER LONGER

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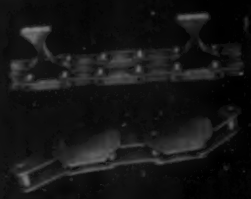
UNION FLEXIBLE COUPLINGS

UNION ROLLER
CHAIN SPROCKETS

UNION APRON
CONVEYORS



UNION
"DESIGNED-TO-APPLICATION"
CHAIN

UNION DRIVE AND CONVEYING CHAIN

Let your H-R power transmission specialist show you how to select the right chain to fit your power drive or materials conveying needs, at "off-the-shelf" savings.

Your H-R specialist is in the best position to give you an unbiased recommendation. He is backed by Union Chain, a division of Hewitt-Robins, with a *complete* line of chain, sprockets, and chain type flexible couplings. He has at his command a wealth of Hewitt-Robins experience in all phases of power drive and materials conveying applications.

Hewitt-Robins sales offices, warehouses, and stock-carrying distributors are conveniently located throughout the United States and Canada. To put an H-R specialist to work for *you*, give your nearest H-R sales office a call.

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UNION CHAIN: *roller chain,* **RT-60;** *engineering chain,* **A-4 . . .**
JONES MACHINERY: *herringbone reducers,* **J-100;** *spiral bevel reducers,* **J-25;** *worm helical reducers,* **J-14;** *shaft mounted reducers,* **J-19;** *in-line helical reducers,* **J-18;** *gearmotors,* **J-17;** *power transmission components,* **J-10A, J-16, J-23;** *complete drive units,* **J-11, J-22.**

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BAKELITE®
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High heat resistance

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Easy processability

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Good mechanical, electrical and chemical properties

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Economical

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Investigate BAKELITE® Polypropylene for MOLDING AND EXTRUSION

(All formulations except food grades are heat stabilized for prolonged use at elevated temperatures)

GENERAL PURPOSE: for molding and extrusion.

HIGH IMPACT: 3 to 5 times tougher than general-purpose materials.

FOOD APPLICATIONS: FDA-sanctioned

HIGH FLOW: for deep-draw moldings

U-V STABILIZED: for outdoor applications

BLOW MOLDING: short flow for parison stability

THERMOFORMING: non-sagging

We would be glad to discuss polypropylene or any of our other plastics materials with you. These include high, medium, and low density polyethylene, polyethylene copolymers, phenolics, styrene, epoxy and vinyl resins and compounds. Simply fill out the adjacent coupon.

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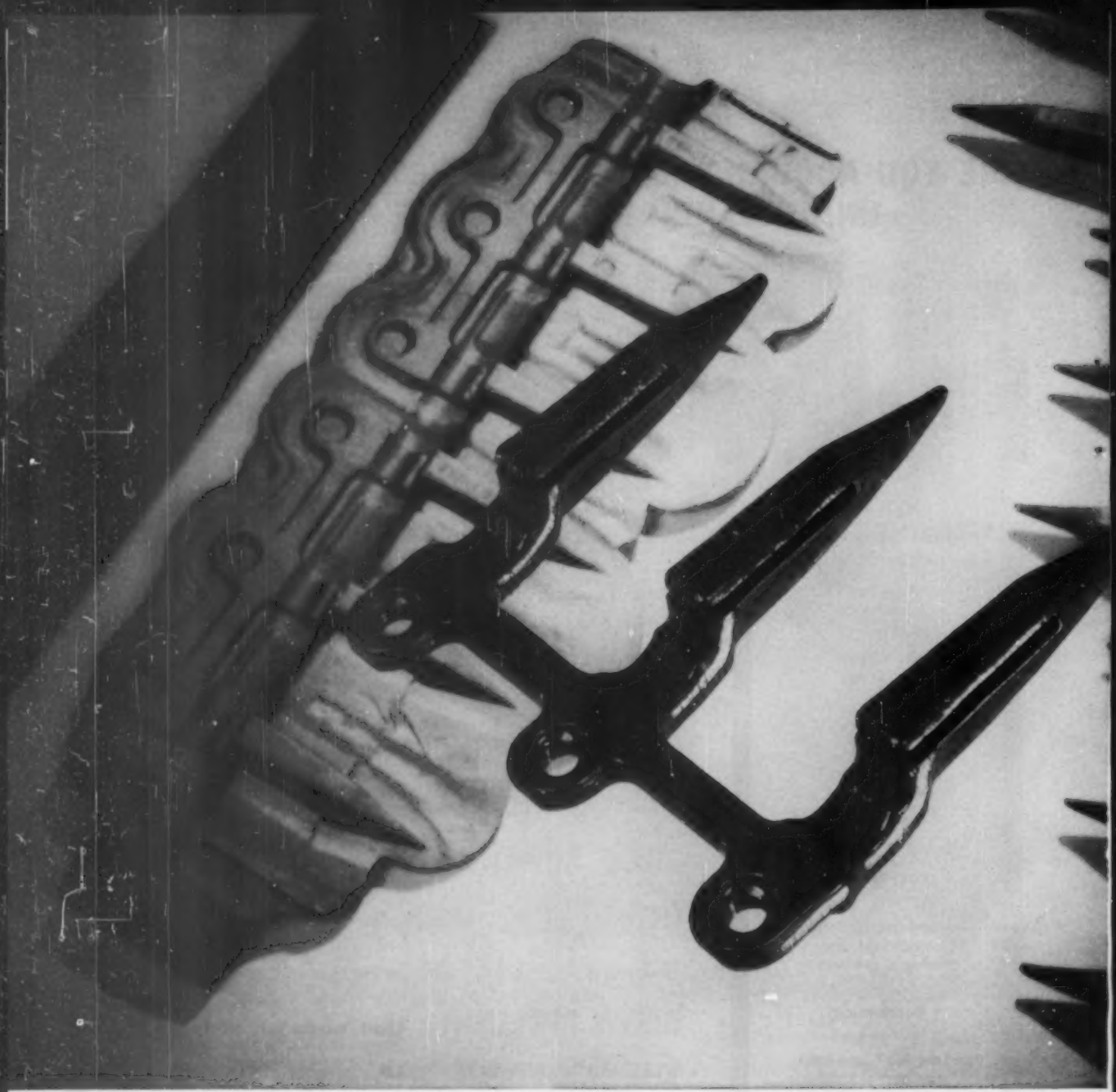


United States Steel offers the widest range of carbon and alloy bar sizes, shapes and grades available in the industry.
We're a single source for all your requirements.

Sickle guard forged from USS Bar Stock for longer life

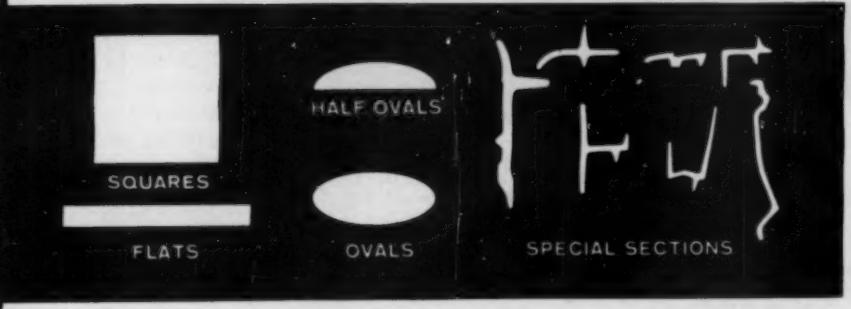
This forged and machined part will last longer than the cast design it replaced even though it weighs 12% less and costs less. It's a sickle guard used on the cutting platform of a line of John Deere self-propelled combines, and is manufactured by Buchanan Steel Products Corporation, Buchanan, Michigan.

John Deere wanted the part to be thinner for maximum cutting coverage at high speeds, and shock- and wear-resistant so that it could self-sharpen the blade. The designers specified forged steel because it would mean a lighter, tougher, more durable part. The part is forged from bar flat steel produced by United States Steel.

Design and fabrication possibilities are virtually unlimited with USS Carbon and Alloy Bar products. Forgings are usually fabricated from USS flats, rounds or round-cornered squares. And nowhere else can you get the range of sizes, shapes and grades offered by USS. You name it —we have it. Just call our nearest sales office, or write United States Steel, Room 6328, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

United States Steel Corporation • Columbia-Geneva Steel Division • Tennessee Coal and Iron Division • United States Steel Supply Division • United States Steel Export Company

This mark tells you a product is made of modern, dependable Steel



USS United States Steel

TRADEMARK

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WHY RISK LOSS OF GEAR SHAPER PERFORMANCE?

Give your products all the high-production, high precision advantages of Fellows Gear Shaper performance by tooling up with Fellows cutters.

The better design of Fellows cutters is the result of advanced engineering techniques, including the use of a high-speed computer for solving design and application problems. Their better quality is the result of constant advances in metallurgy and manufacturing methods. And, proof of their better performance are the thousands of Fellows cutters in use on modern gear production lines.

Fellows cutters on Fellows machines lower costs and speed production on external and internal, spur and helical involute gears and a wide variety of non-involute shapes as well. All Fellows Offices are at your service for providing information.

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THE PRECISION LINE **Fellows** *Gear Production Equipment*

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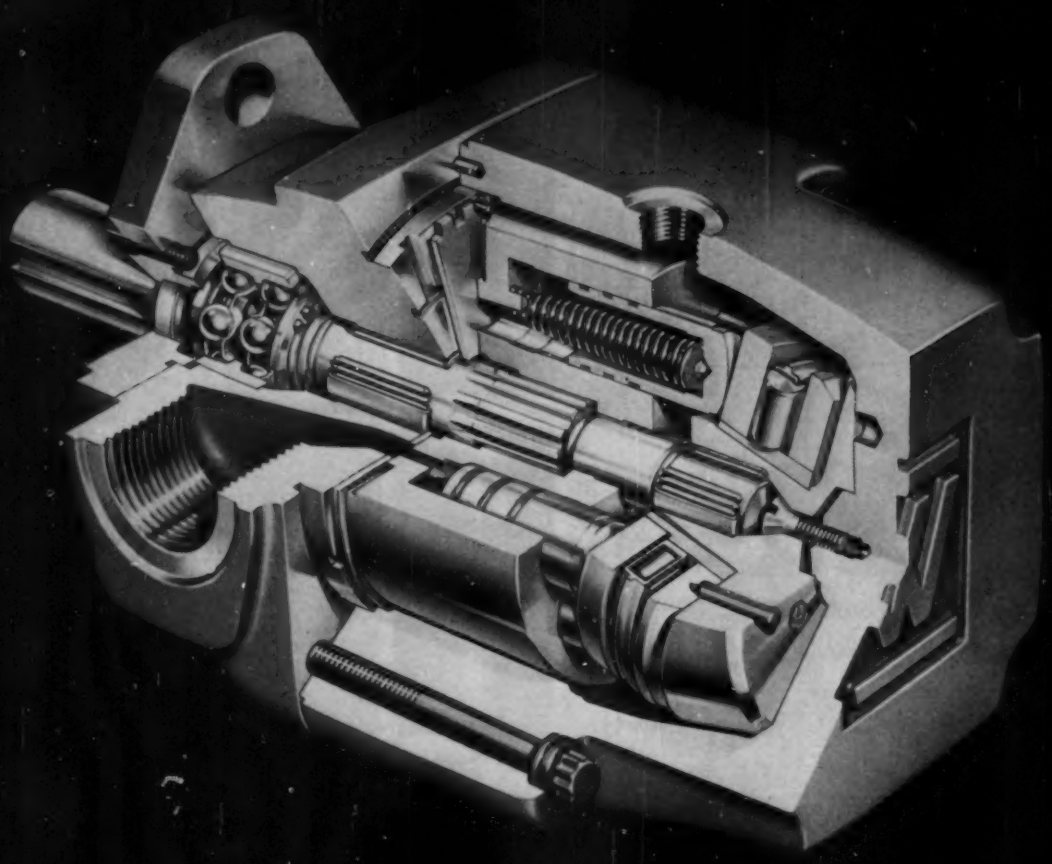


WEBSTER'S NEW C3F PISTON MOTOR AND PUMP

compact, simple design ■ exceptionally serviceable!

This new hydraulic power unit — developed especially for the machine tool field — features unique application and servicing advantages. Examples: (1) small "package" to fit in close quarters — SAE "A" size mounting can be used with easy access to both mounting holes; (2) simplest axial-type piston pump on the market — fewest parts, fewer potential trouble spots, greater economy; (3) easily serviced — all critical moving parts can be readily replaced in the field. Shaft can be exchanged by disassembling seal end only; (4) unit can be disassembled and the rotation reversed in the field — can be arranged for use as a dual rotation motor; (5) variety of mounting styles — mounting plate and seal assembly is a separate piece and can be furnished in several mounting styles; (6) drive shafts are available with keyways or splines.

The C3F Series can be used as a hydraulic motor (remote rotary locations, screw feeds — anywhere an electric motor might be used) or as a hydraulic pump. . wherever high torque and smooth, steady force are required. It is available in four sizes — from .72 to 1.81 cubic inches per revolution. Capacities range from 3.3 to 8.5 gpm at 1200 rpm; 7 to 18 gpm at 2400 rpm.

C3F SERIES

FIXED DISPLACEMENT AXIAL-TYPE PISTON MOTORS AND PUMPS

Drive: direct, gear or belt

Displacements: four sizes; .72, 1.09, 1.45, 1.81 cu. in. per rev.

Porting: Side ports — horizontal or vertical — handle 1" NPT inlet or 1¼" "O" ring straight thread

Capacity: 3.3 to 8.5 gpm at 1200 rpm
7 to 18 gpm at 2400 rpm

Speeds: to 3000 rpm

Pressures: continuous duty 3000 psi, intermittent rating to 3500

When used as motor:

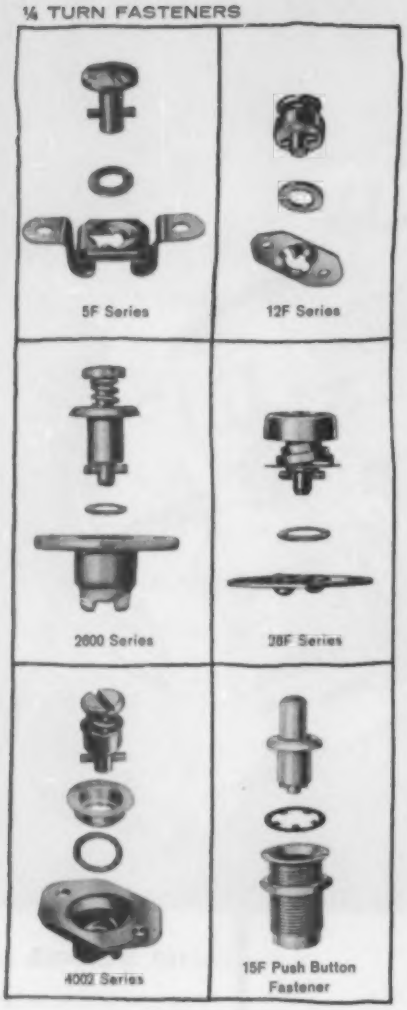
Torque range (theoretical): four sizes; 11.52, 17.28, 23.04, 28.80 inch pounds per 100 psi

Output: 5.5 to 14 hp. at 3000 psi at 1200 rpm
11 to 28 hp. at 3000 psi at 2400 rpm

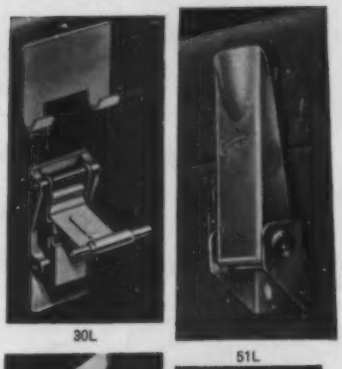
OIL HYDRAULICS DIVISION
WEBSTER ELECTRIC
RACINE · WIS

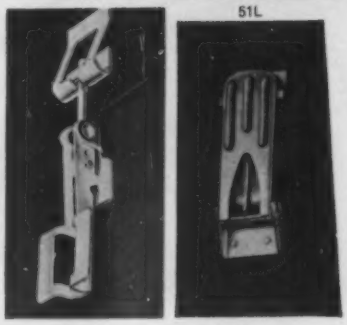
Circle 253 on Page 19

¼ TURN FASTENERS



UNIVERSAL LATCHES





CHASSIS LATCHES

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FASTEN/ATION

The mechanics of modern fastening have matured to the point where it is now considered a science. We call it FASTEN/ATION.

Your designs are important enough to build, and should be covered and protected . . . but you must be able to remove the covering in a hurry. Here's where Camloc's FASTEN/ATION becomes significant to you. Installation is simple – closure is simple – opening is even simpler, and each of these operations takes only seconds.

The final touch to a good design includes the best method of fastening, the simplest installation and use, and a fastener that complements the product in size and appearance. Since making a decision involves the evaluation of alternatives, here are some of Camloc's more popular fasteners. We know you will want to make a more careful analysis before you specify, we suggest that you write for our complete catalog. Be FASTEN/ATED! Let us FASTEN/EER your next design.

specialists in fasteners for industry

CAMLOC

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West Coast Office, 5455 Wilshire Blvd., Los Angeles, California • Southwest Office, 2509 W. Berry St., Fort Worth, Texas
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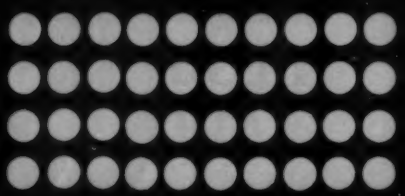
A GRAPHIC, MONEY-SAVING STORY OF REVERE BRASS ROD

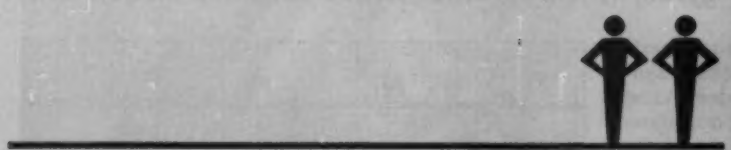
BEFORE using Revere Brass Rod

10 INSPECTORS



REJECTS RAN AS HIGH AS 40%

AFTER using Revere Brass Rod



2 INSPECTORS

ONLY 6 REJECTS IN 30,000 PIECES

A prominent manufacturer of electronic gear was having difficulty with wafer-like brass discs used to maintain the fidelity of tone in its equipment. Rejects were running as high as 40% and a staff of ten inspectors was needed to keep tabs on these seemingly-minor parts.

Revere's Technical Advisory Service was called in for consultation with the manufacturer's engineers. Working together, they found the reasons for the high rejection rate . . . ordinary free-cutting brass rod from which the discs were cut, just couldn't do the job properly. Likewise they found the solution.

Rigid control of molecular structure of the alloy . . . "kid glove" treatment at the Revere mill . . . careful quality control all down the line . . . these produced a brass rod that cut the number of inspectors from ten to two and the rejects from as high as 40% to a startling low of six pieces in 30,000!

Although this rod has a premium price tag, such great savings per-unit are possible that even the most exacting purchasing executives have been unable to work out a better way to handle the problem.

This story is typical of the kind of savings that can be realized when you work hand-in-glove with your suppliers. It shows how higher first costs sometimes can be made to become lower final costs. Why not bring *your* metal problems to Revere for solution?

REVERE

COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801

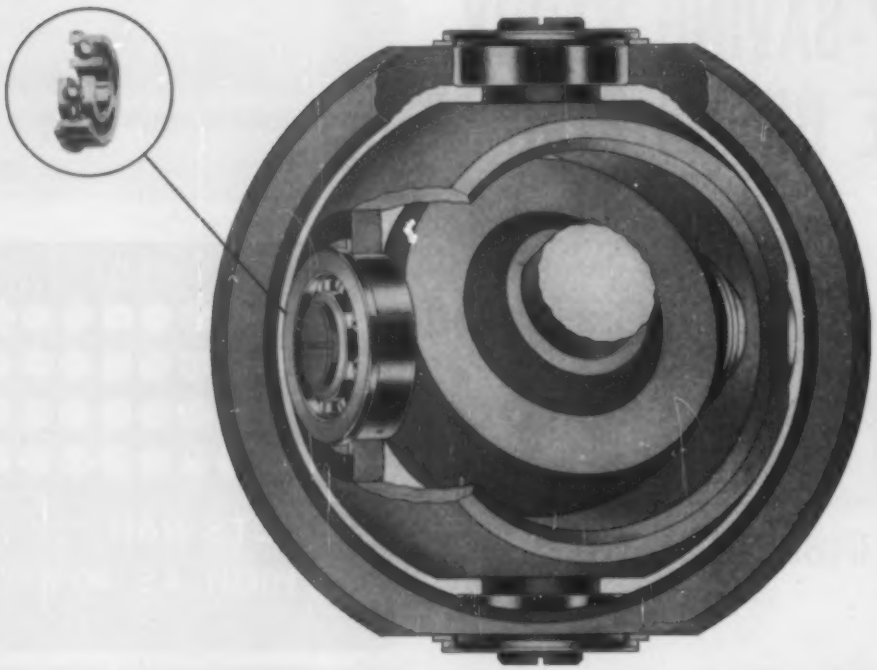
Executive Offices: 230 Park Ave., New York 17, N. Y.

Mills: Rome, N.Y.; Baltimore, Md.; Chicago and Clinton, Ill.; Detroit, Mich.; Los Angeles, Riverside and Santa Ana, Calif.; New Bedford and Plymouth, Mass.; Brooklyn, N.Y.; Newport, Ark.; Ft. Calhoun, Neb. Sales Offices in Principal Cities.

Distributors Everywhere

Circle 255 on Page 19

BARDEN "W" retainer bearings
reduce torque peaks...
eliminate retainer lock...
deliver uniformly low-torque performance



Low-torque bearing reliability for gyros, synchros, other torque-sensitive instruments

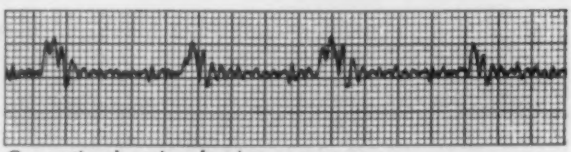
Torque peaks that fail to show up on most torque tests can result in erratic performance of gyro gimbals, synchros, potentiometers and other instruments demanding uniformly low torque or exceptionally smooth operation. To solve this reliability problem, Barden developed the "W" retainer bearing.

The "W" retainer is a thin-section, free-fitting stainless steel ball cage with formed pockets. Its design reduces internal bearing friction, cuts down torque peaks and eliminates retainer lock (wedging of balls and retainer under radial or combined axial-and-radial loading, or as a result of misalignment).

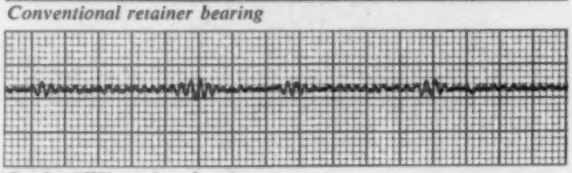
Barden "W" retainer bearings have higher load and speed capacity than spring retainer bearings, yet have the same advantage of low-torque operation under misalignment. Compared with conventional ribbon retainer bearings, "W" retainer bearings have lower overall torque and greatly reduced torque peaks, particularly under radial or combined loads (see traces at right).

Data Sheet Available

New data sheet lists 81 *Barden Precision* "W" retainer bearings now available in 16 standard miniature and instrument sizes, flanged and unflanged, shielded and open, from .0469″ to .2500″ bore and .1562″ to .6250″ O.D. Ask for Data Sheet W-3.



Conventional retainer bearing



Barden "W" retainer bearing

In torque test (4.5 lb. radial load, 18 rpm, no induced vibration) conventional ribbon retainer instrument bearing develops peaks 11 gm-cm above average torque. Barden "W" retainer bearing shows torque peaks of only 3 gm-cm under same test conditions. Traces show high torques possible in actual operation under radial loading. These cannot be compared with readings from MIL-STD 206 testers which show torque under thrust load only.

Traces: actual size. Scale: 1 mm = 2 gm-cm.

BARDEN
PRECISION BALL BEARINGS

THE BARDEN CORPORATION, 208 Park Ave., Danbury, Conn., Pioneer 3-9201
3850 Wilshire Blvd., Los Angeles 5, Calif., DUnkirk 5-0034

Replace old-fashioned couplings with Rockwell-Standard's

BLOOD BROTHERS

HEAVY-DUTY INDUSTRIAL DRIVE LINES

ROCKWELL-STANDARD ENGINEERS specifically designed Blood Brothers Heavy-Duty Industrial Drive Lines to replace couplings in industrial applications. They improve machine performance and efficiency...last longer... give better service than any coupling. They often reduce costs by eliminating the need for bearings and supports required by conventional coupling installations. Wearing parts are quickly replaced and even drive lines can be replaced in 15 minutes!

Available in capacities up to 500,000 torque inch pounds, they are adaptable to a variety of applications—rolling mills, oil field equipment, irrigation pumps, cargo carriers, marine drives, logging winches, mining machinery and many others.

Blood Brothers Industrial Drive Lines offer these special features:

• Wing bushings that eliminate costly flange yokes and reduce down time during servicing. Simply remove 8 bolts for complete disassembly • Sliding spline provides for quick, easy assembly—variations in mounting locations—longitudinal shaft movements during operation—deflections and temperature changes • Easy access to lubrication fittings.

Another Product of...

ROCKWELL-STANDARD CORPORATION

Universal Joint Division, Allegan, Michigan

Circle 257 on Page 19

5 NEW DIESELS

- **Heavy-duty design in a compact engine**
- **Smooth, high-speed operation**
- **Interchangeability of wearing parts**
- **Controlled temperature cooling**
- **Gear pump force-feed lubrication**
- **12-volt electrical system**
- **Push-button glow plug starting**
- **Famous International parts and service**

SPECIFICATIONS

Model	No. Cyl.	Bore x Stroke	Disp. (cu. in.)	Length (in.)	Width (in.)	Height (in.)	Engine Weight (lb.)	Max. hp	Int. hp	Cont. hp	Torque (lb./ft.)	Fuel Consumption (lbs./hph)
DU-66D	2	3.25 x 4	66.3	21.22	20.25	30.37	408	15.8	14.2	12.6	36.5	.457
DU-74-D	2	3.44 x 4	74.3	21.22	20.25	30.37	410	17.4	15.7	13.9	42.5	.457
DU-99-D	3	3.25 x 4	99.5	25.50	23.09	30.00	520	22.8	20.5	18.2	65.0	.477
DU-111-D	3	3.44 x 4	111.3	25.50	23.09	30.00	524	24.6	22.2	19.7	72.0	.477
DU-132-D	4	3.25 x 4	132.7	29.75	23.00	30.12	589	39.6	35.6	31.6	97.0	.464

Horsepower ratings shown above are for engine with fan, radiator, clutch, air filter and generator at 2,000 RPM except for UD-132-D which is 2,400 RPM. Max. torque at 1,200 RPM. Dimensions and Weights are from fan to back face of flywheel housing and do not include PTO or air cleaner.

12 to 40 hp

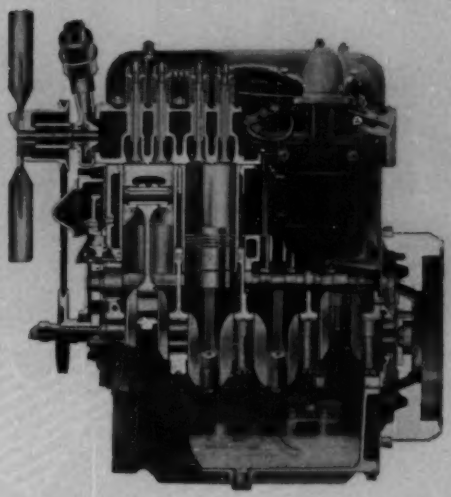
International sets new standards of performance with heavy-duty design in compact, economical engines...

Here's eager, dependable power for those jobs where the load is moderate but the duty is rugged. Now you can put a hefty, field-proved International Diesel on water pumps, water well drill rigs, refrigerating units, generators, conveyors, lift trucks, tractors, compressors, asphalt mixers, blowers, sprayers, compactors, cranes, pipeline equipment, locomotives and small crushers. These two, three and four cylinder International Diesel engines, from 12 to 40 horsepower, bring the complete IH line up to 62 models—including the largest line of Diesels in the industry.

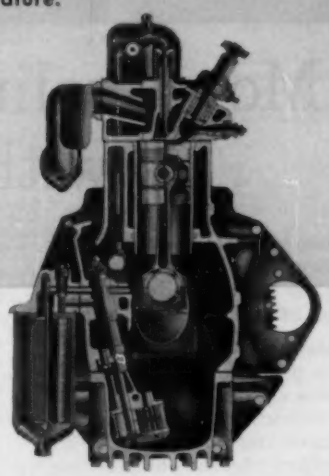
All five models are direct-starting, valve-in-head, sleeved engines with 19.1 compression ratio. The power unit hood is hinged for easy access to fuel tank, cooling system, oil pan and battery. Operating levers and instruments are grouped for easy, one-hand control and operator convenience. Maximum flexibility is achieved with optional attachments—you specify exactly what you need, from bare engine to complete power unit.

Check the full IH line of Diesel and carbureted engines—8 to 385 hp—and discover the extra selling advantages International power adds to your products. Call or write to International Harvester Co., Engine Sales Dept., Melrose Park, Ill.

Simple, rugged design assures maximum efficiency and easy servicing...



Economical operation is assured with full-firing efficiency of IH swirl-type pre-combustion chambers. Built-in governor maintains selected rpm despite varying loads. Replaceable main and connecting rod bearing shells have extra large bearing surface for longer operating life. Gear pump force-feed lubrication assures continuous flow of lube oil to all bearing surfaces. Pump-circulated cooling system with thermostatic control and radiator curtain provides quick warm-up and efficient operating temperature.



Interchangeability of many parts and attachments brings you unmatched advantages in power standardization

These new IH engines are designed with interchangeable connecting rods, main and connecting rod bearings, valves, valve springs, push rods, and rocker arm assembly components. Crankcases are machined from three basic blocks, and pistons and sleeves are of two sizes. Many attachments are interchangeable. And you get further model-matching advantages with the smaller carbureted engines in the International line.

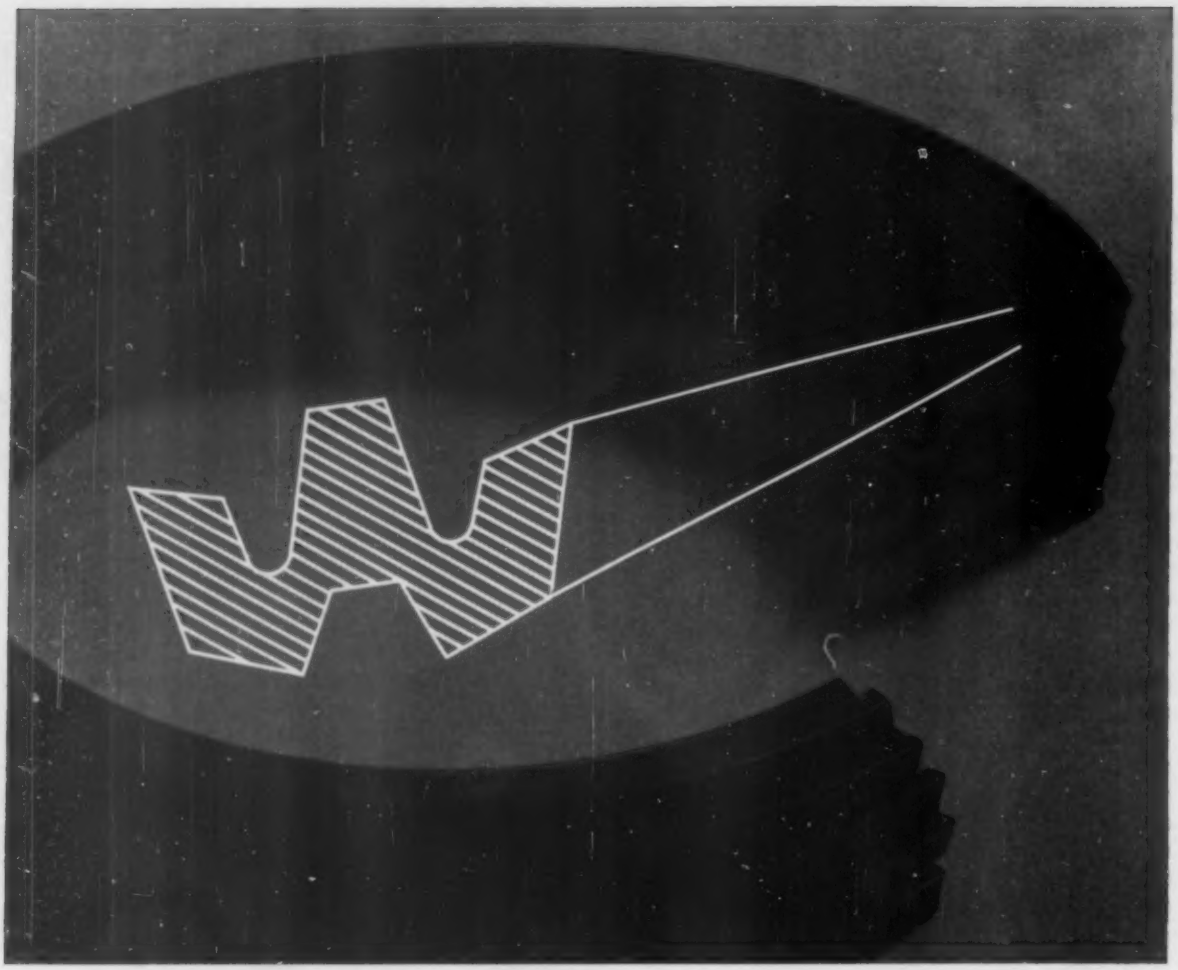
INTERNATIONAL®

IH ENGINES

International Harvester Co., 180 North Michigan Ave., Chicago 1, Ill.

A COMPLETE POWER PACKAGE

Circle 258 on Page 19



More sealing ability in less space with J-M UNEEPAC®

THIS CROSS-SECTION DESIGN DEMONSTRATES WHY UNEEPAC AFFORDS FULLY AUTOMATIC SEALING, EVEN IN LIMITED SPACE.

J-M Uneepac is designed and engineered to provide a truly automatic lip-packing element for use in applications requiring multiple ring sets in minimum stuffing box depths.

The design has many outstanding features. The rings nest together in an interlocking manner, but lips still have freedom to flex at the hinge and be pressure-actuated. Each ring is an individual sealing element, and does not require compression adjustment against adjacent rings to make it seal initially or during its life.

Easy-to-assemble Uneepac Rings offer peak sealing efficiency at optimum economy. They seal against the most rugged conditions, and give exceptional service life in rod and piston applications. They fit accurately and reduce friction. Uneepac Rings are precision-moulded, skillfully compounded in whatever materials best meet your requirements. A complete range of standard sizes, styles and materials is available for immediate shipment. Or, Johns-Manville will design and custom-make the exact packing you require.

And in light-duty applications where space is not available for multiple-ring sets, J-M Deep Base Uneepac Packing offers important economies. This simplified single-ring version of the Standard Uneepac design, engineered for reciprocating piston and rod application in air and low pressure hydraulic service, provides lower break-away load, less friction and smooth, dependable action.

You will find all J-M moulded packings materials and designs in the new booklet PK-173A . . . with specific recommendations for most applications and service conditions. For a free copy, or for help with any sealing problem, see your J-M Distributor. Or write to Johns-Manville, Box 359, New York 16, N. Y. In Canada: Port Credit, Ont.

JOHNS-MANVILLE

JOHNS MANVILLE JM PRODUCTS

Circle 259 on Page 19

For YOUR cylinder requirements

T-J SALES and SERVICE ...COAST to COAST

Tomkins-Johnson Sales and Factory Service Engineers can offer you valuable assistance in the proper selection and use of any T-J cylinder to its proper power application, whether O.E.M. or replacement. They are also well qualified to assist your project engineers in the design phase of most all pneumatic or hydraulic power systems. T-J Sales and Service Engineers are located throughout the entire United States and Canada for immediate service. Contact your nearest T-J representative, or T-J direct.

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Birmingham 12, Alabama
Phone: Alpine 26101

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Los Angeles 58, California
Phone: Ludlow 8-5107

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Los Angeles 58, California
Phone: Ludlow 8-5107

Ralph W. Atkinson Co., Inc.
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Phone: Yukon 2-5188

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Phone: Sherman 4-1311

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Phone: Woodland 5-0141

Moehlenpah Engineering
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St. Louis 10, Missouri
Phone: Jefferson 3-0325

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Indianapolis, Indiana
Phone: Walnut 6-4053

Weldon Engineering Company
7315 Harold Drive
Fort Wayne, Indiana
Phone: TR 3-4550

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Union Arcade Bldg., Room 605
Davenport, Iowa
Phone: 3-5701

Moehlenpah Engineering
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Jackson, Michigan
Phone: ST 4-2229

Fluid Systems Engineering Company
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Detroit 13, Michigan
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Phone: LU 6-6474

Tri-Line Corporation
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Allan T. Shepherd Company
P. O. Box 1423
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Henry M. Wood Company
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Axminster 1-7797

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Portland 10, Oregon
Phone: CA 2-3285

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Phone: Clearbrook 9-1313

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Milwaukee 14, Wisconsin
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Phone: Clearwater 6-2331

Geo. T. White Co., Ltd.
Montgomery Dr.
Ancaster, Ont.
Phone: MI 8-4487

T-J TOMKINS-JOHNSON
2425 W. Michigan Ave., Jackson, Michigan

Circle 3000 on Page 19

Simple, isn't it?

— and the time it saves!

Save an hour, two hours, three hours per change, and *you* figure what Taper-Lock mounting is worth to you!

Here is the simplest, surest method of mounting wheels on shafts. So superior that 160 manufacturers of mechanical power transmission parts use this mounting in their products—under license from Dodge. No other mounting system is so universal. Taper-Lock holds as though it were a shrunk-on fit. Yet by the simple use of its jack screws it "unlocks" like magic. No damage to shaft or machinery—no grunt nor groan nor wasted time.

Taper-Lock mounting is one of the plus features of Dodge sheaves, sprockets, couplings, conveyor pulleys. Ask your Dodge Distributor, or write us for bulletin.

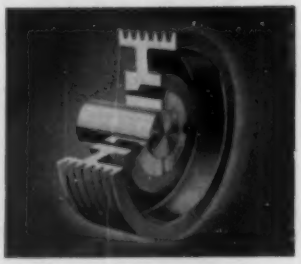
Dodge Manufacturing Corporation, 3300 Union Street, Mishawaka, Indiana

The Products with the Pluses...

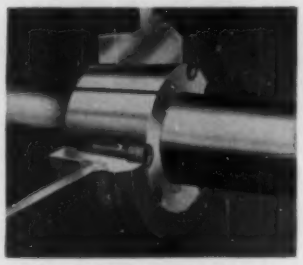
DODGE

of Mishawaka, Ind.

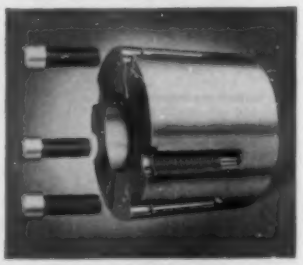
CALL THE TRANSMISSIONEER, your local Dodge Distributor. Factory trained by Dodge he can give you valuable assistance on new cost-saving methods.



No flange, no collar, no protruding part! Modern, safe, *flush* design. Minimum space on shaft. Mounts as a unit — tighten while sighting. Easy on — easy off!



Bearing surface runs the entire length of the hub and bushing. Full compression means extreme holding power. No wobble. Taper-Lock runs true!



Interchangeable bushings. Change from shaft to shaft, from one size to another, from sheaves, to sprockets, to couplings, to pulleys. Talk about inventory economy!

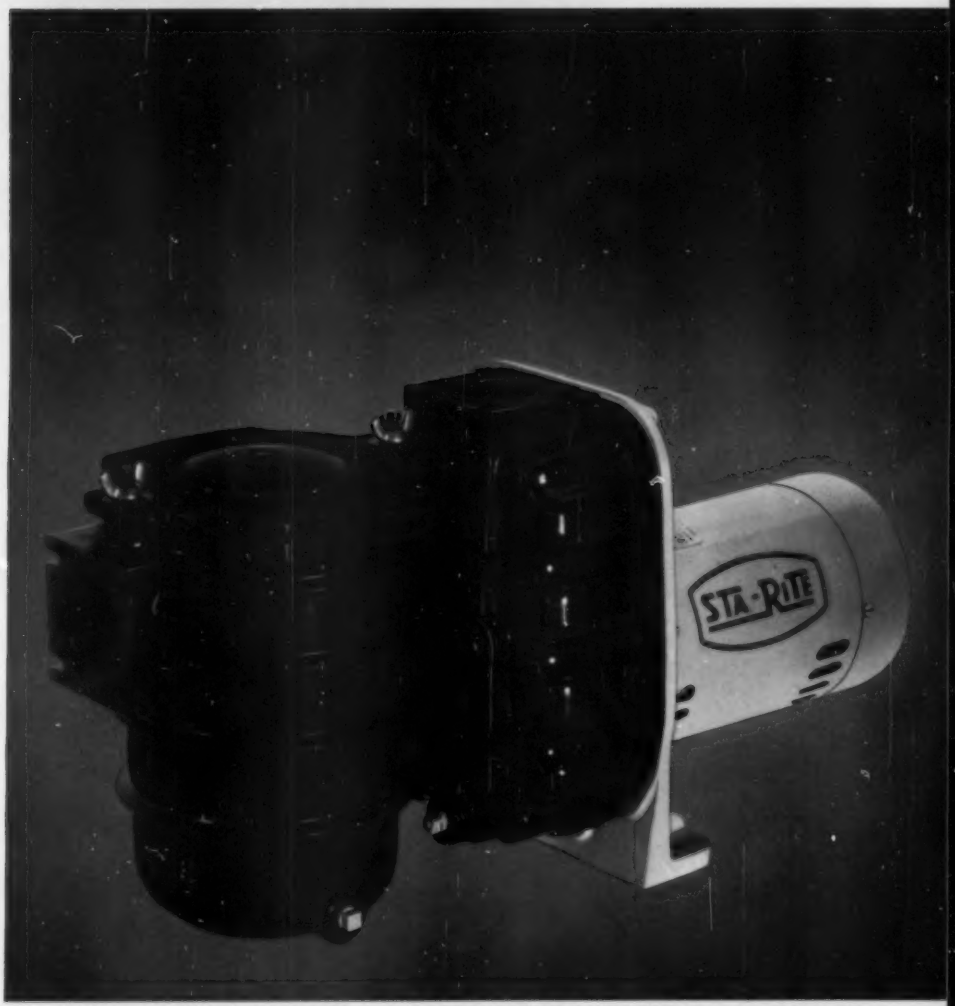
Circle 261 on Page 19

Circle 262 on Page 19→

working with

DuPont **Delrin**

one of Du Pont's versatile engineering materials



Parts of DELRIN molded by Burlington Molded Products Co., Burlington, Wisc., for STA-RITE Products, Inc., Delavan, Wisc.

Corrosion-proof parts of DELRIN® meet rugged requirements of new swimming-pool pump

Swimming-pool pump must resist corrosion, abrasion and galvanic action. Parts of DELRIN acetal resin in new self-priming pump do just that. Field testing of pumps shows excellent results: burst tests included pressures up to 190 psi.

The pump has a body, suction trap and trap cover of DELRIN. These parts, among the largest ever molded of DELRIN, weigh a total of seven pounds. The pump (1/3-2 h.p.) is designed for use with swimming-pool filters and has a maximum capacity of 120 GPM and a shutoff head of 100 feet.

In addition to being corrosion-proof, DELRIN provides the pump parts with (1) high hoop strength and creep resistance to withstand the large stresses resulting from internal water pressure, (2) outstanding fatigue endurance under cyclic pressures, (3) good shear and thread strength to permit direct installation of piping to pump, (4) retention of metal inserts in pump body without cracking or crazing around inserts.

Turn page for other examples of how the properties of DELRIN acetal resin improve performance and reduce costs of products in other industries.

DU PONT

REG U.S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING THROUGH CHEMISTRY

working with

Du Pont Delrin

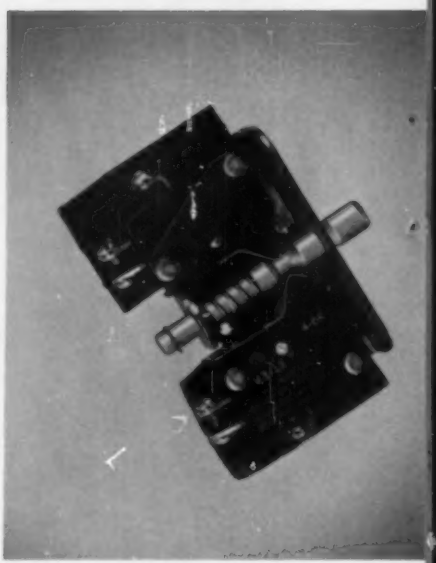
acetal resins

one of Du Pont's versatile engineering materials

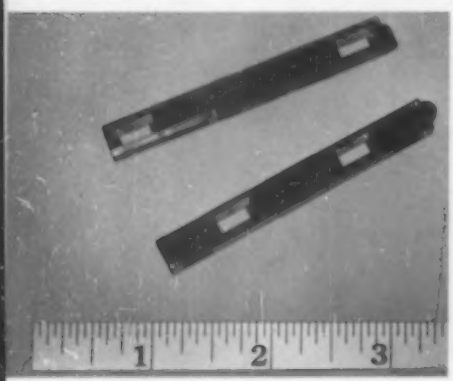
Three more ways Du Pont DELRIN® outperforms metals

Du Pont DELRIN acetal resin has, in the space of a few short years, replaced parts made of many different metals in nearly every major industry. This is because designers find that in addition to strength and durability, DELRIN offers them advantages over metals in corrosion resistance, electrical and heat insulation, colorability, lightness, resilience and the opportunity to design one-piece multifunctional parts.

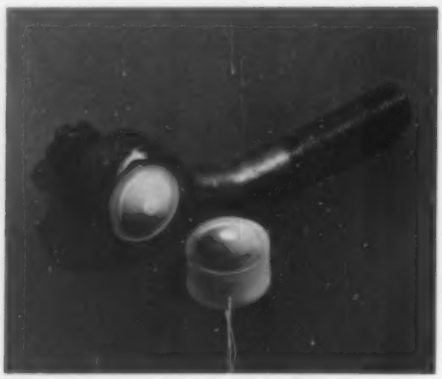
Why not investigate the advantages of using DELRIN in the products you make and the products you use? To learn more about DELRIN, just mail in the coupon below.



Door interlock switch plungers molded of DELRIN assure switches an extra-long life. Although the average life expectancy of these switches is normally 100,000 operations, they have survived even 1,000,000 operations in satisfactory condition, outwearing previously used steel 5 to 1. Plungers of DELRIN operate smoothly without lubrication and have high strength and exceptional wear resistance. The switches are commonly used in panels for electronic equipment. (MICRO SWITCH, a division of Honeywell, Freeport, Illinois.)



Electric typewriter carriage roller trucks molded of DELRIN are stiff and strong, yet are resilient enough to flex and accept steel rollers which snap-fit into holes. This design is not economically feasible in metals. Use of corrosion-proof DELRIN has practically eliminated assembly problems such as flash or breakage. (Molded by Hydro Plastics, Inc., Georgetown, Kentucky, for IBM Corp., Electric Typewriter Division, Lexington, Kentucky.)



Steering linkage ball seats molded of DELRIN give "greased for life joints" on many 1962 automobiles. Replacing older steel-to-steel joints, new joints with the low coefficient of friction of DELRIN give a smooth, even feel to steering. DELRIN is tough over a wide range of temperatures (-40°F. to 250°F.). Severe tests proved that DELRIN has the dimensional stability and resistance to creep needed for a permanent tight fit, sealing in the lubricant.

POLYCHEMICALS DEPARTMENT

DU PONT

REG. U.S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING
. . . THROUGH CHEMISTRY

E. I. du Pont de Nemours & Co. (Inc.), Dept. 5 A
Room 2507D Nemours Building, Wilmington 98, Delaware B

I am interested in evaluating DELRIN for the following use:

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*Name*_____

*Company*_____ *Position*_____

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*City*_____ *Zone*_____ *State*_____

In Canada: Du Pont of Canada Limited, P. O. Box 660, Montreal, Quebec.

DELRIN *acetal resins*

one of Du Pont's versatile engineering materials

Alathon · Zytel · Lucite

BCA DELIVERS NEW DESIGN DATA

for personal discussion on all ball bearing applications!

Whenever BCA submits engineering drawings and calculations to a customer for a new ball bearing application, they're delivered in person by a BCA engineer. He can discuss the problem and our suggested solution, explaining how and why this particular design is best for the job to be done. Only in this way can you get the personal consultation essential to solving many bearings problems.

When new ball bearing applications or design changes are required, BCA engineers to the precise degree that operating conditions require. Bearings *must not* be under-engineered, at a risk of bearing failure: neither should they be over-engineered, at unnecessary extra cost. These are but a few of the factors which must be considered in bearing design. This is why the BCA personal approach offers a decided advantage to our customers.

Another important BCA "extra" is unusual flexibility in operation. Because we can eliminate red tape and wasted time, many of our customers have found we can even handle delivery or production emergencies in good order.

BCA also has available complete new research and engineering facilities and equipment. Included are special bearings testing machines which can duplicate many of the customers' actual operating conditions.

BCA makes ball bearings for OEM and replacement use, for almost every industry . . . construction, agriculture, automotive, machine tool. They're available in a complete range of sizes and types. For information or for technical assistance on bearings problems, contact Bearings Company of America, Division of Federal-Mogul-Bower Bearings, Inc., Lancaster, Pa.

BEARINGS COMPANY OF AMERICA

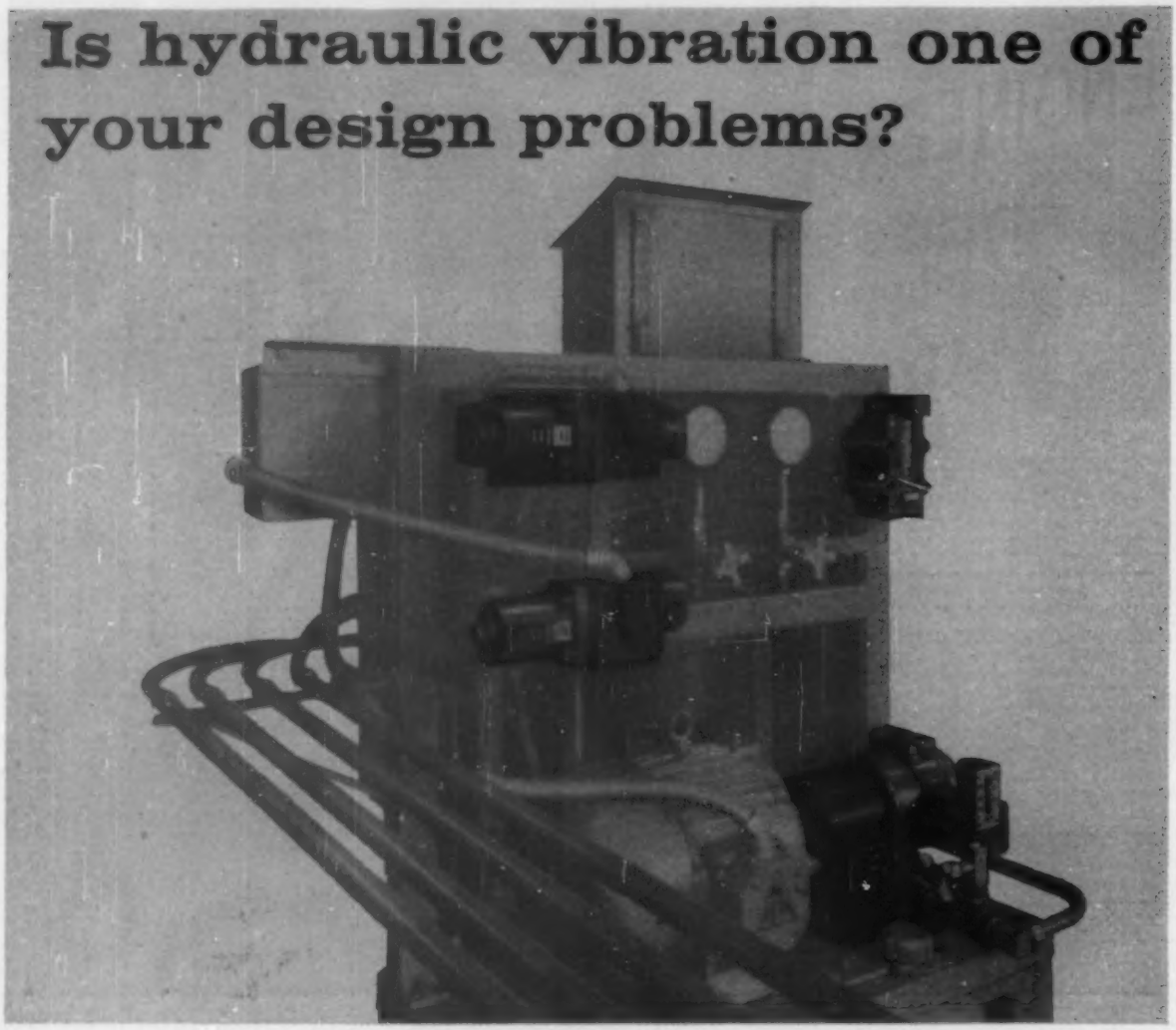
ball bearings

DIVISION OF
FEDERAL-MOGUL-BOWER
BEARINGS, INC.

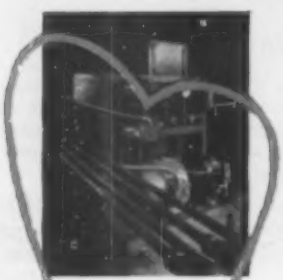
←Circle 262 on Page 19

Circle 263 on Page 19

Is hydraulic vibration one of your design problems?



Scans Associates solved this problem with a Racine Hydraulic System



Porosity testing machines manufactured for major Detroit transmission plant by Scans Associates, Livonia, Michigan.

"It would take an Act of Congress to make us use any equipment except Racine components for our porosity testing machines," says Mr. Vernon G. Converse, President of Scans Associates, Livonia, Michigan. The machine — which makes 4 different leakage tests on transmission cases in a 20-second cycle — must check porosity to ¼ inch of water pressure. The machine hydraulically clamps the part firmly in place and tightly plugs all openings. Air pressure and vacuum are alternately applied inside the part, and changes in pressure are pneumatically measured. The slightest hydraulic vibration would distort the readings. "This demands hydraulic equipment that is both extremely sensitive and steady," states Mr. Converse. "Racine has always met both requirements perfectly." The Racine system in this application consists of a Model S variable volume pump, a self-contained 30-gallon reservoir, a 5HP motor and 3 Racine valves (one of them for pressure reduction).

If your application demands sensitivity and precision in hydraulic control, a compact Racine system can meet your requirements.

RACINE HYDRAULICS & MACHINERY, INC. RACINE, WISCONSIN

We're interested in knowing more about Racine Hydraulic Systems. The application of interest to us is _____

NAME _____ TITLE _____

FIRM _____

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CITY & ZONE _____ STATE _____

RACINE

RACINE designs systems to solve hydraulic problems

new from Warner Electric

easier mounting, greater torque-for-size Electric Clutch

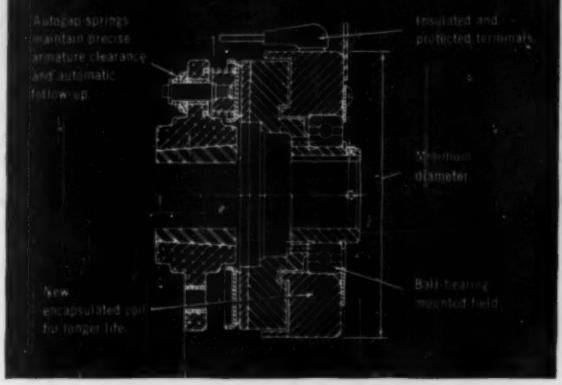
New Warner SF 500 clutch
Static torque rating—50 lb-ft

This new rugged and reliable Warner SF 500 electric clutch combines minimum size with maximum torque—up to 50 lb-ft static. It offers simplified mounting (no collector rings or brushholder) of the ball-bearing-mounted stationary field.

The new encapsulated coil delivers peak reliability, longer life under the severest operating conditions. Minimum axial dimension permits installation of the new SF 500 in smaller space than ever before possible—yet it replaces existing units without reworking or machining.

Improve *your* machine control economically, simply—with the new Warner SF 500 stationary-field clutch. It eliminates complex hydraulic, air, or mechanical linkages—gives you the simplest, most reliable control on the market today. Warner stationary-field electric clutches are now available in torque ratings from 1.5 lb-in. to 1350 lb-ft. Write today for full details.

Check the advanced design features of this new SF 500 clutch


Autogap springs maintain precise armature clearance and automatic follow-up
Insulated and protected terminals
Minimum diameter
New encapsulated coil for longer life
Ball-bearing mounted field

----WARNER ELECTRIC----

Warner Electric Brake & Clutch Co., Dept. MD-12, Beloit, Wisconsin

I'm interested in the new SF 500 clutch. ☐ Send me full specifications. ☐ Have a salesman call.

☐ Send data on complete Warner line of electric brakes and clutches.

Name_____

Title_____

Company_____

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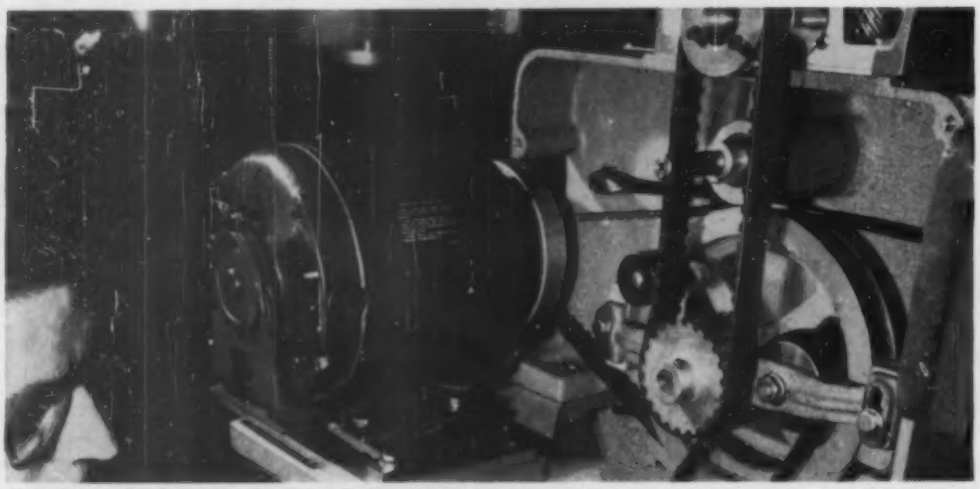
City_____ Zone_____ State_____

Stocked by Authorized Distributors in Principal Cities Throughout the World

Circle 265 on Page 19

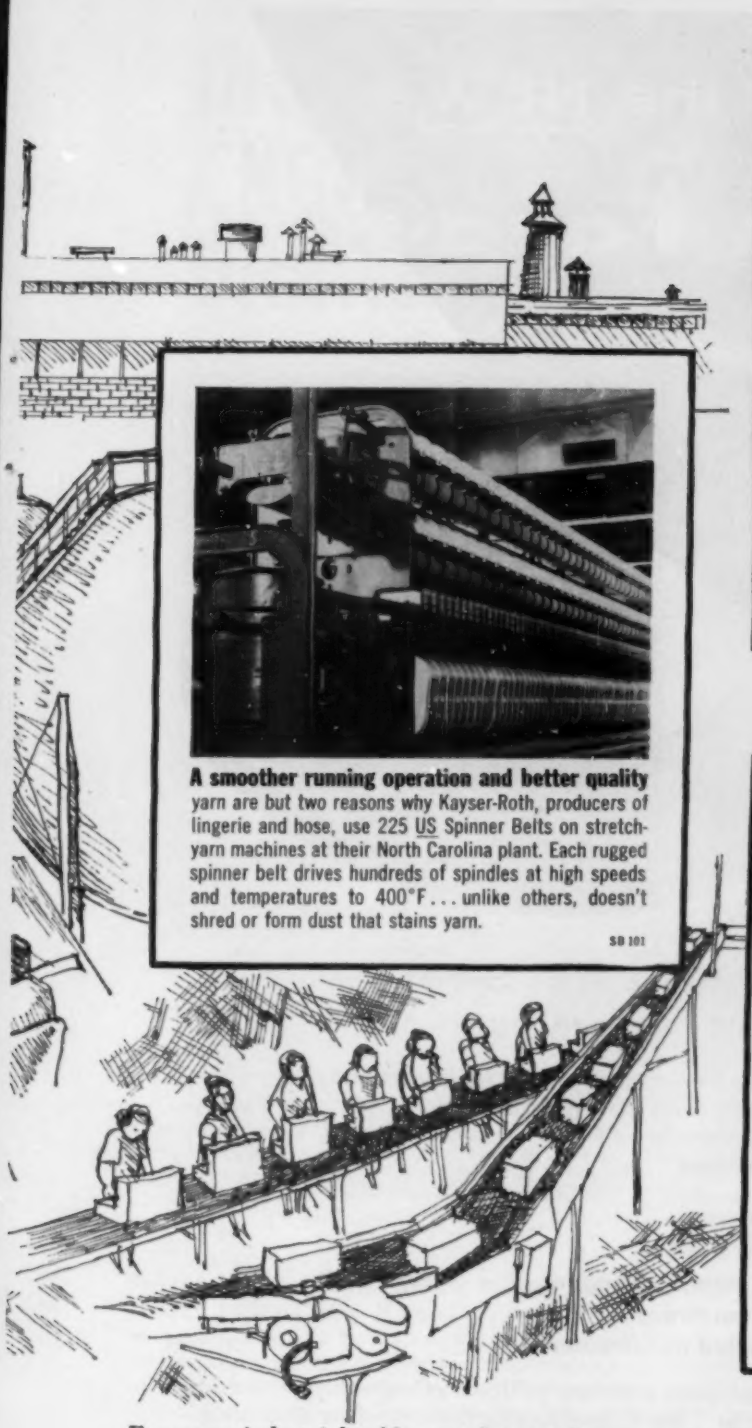
AT THE HEART OF INDUSTRY...



Teaming up for better projection...better sound, dependable US V-Belts and "Timing"® Belts are vital to the performance of Century movie projectors. These projectors must often run 12 hours in a row. The US belts insure silent running, keep projectors going at the exact speed required, guard against audience-annoying breakdowns.

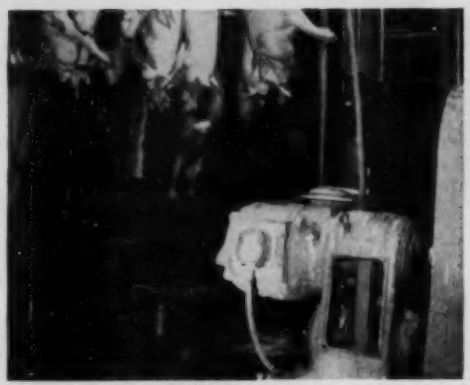
VB 105

When industry wants power, in plant or product, it gets it with the help of US. Time after time, design engineers find they get more power, more efficiently...and at less cost...with U.S. Rubber products. For your needs in rubber, see US, the world's largest producer of industrial rubber goods.



A smoother running operation and better quality yarn are but two reasons why Kayser-Roth, producers of lingerie and hose, use 225 US Spinner Belts on stretch-yarn machines at their North Carolina plant. Each rugged spinner belt drives hundreds of spindles at high speeds and temperatures to 400°F... unlike others, doesn't shred or form dust that stains yarn.

SB 101



More than 6 times the life of other Variable Speed Belts, reports the Storm Lake, Iowa, plant of Hygrade Food. The first US Variable Speed Belt installed has already outperformed the previous belts by more than 6 to 1. What's more, it required no dressing or other maintenance and, unlike previous belts, has not developed uneven edge wear which shortens equipment life.

VSB 101

Chosen for overall top performance, U.S. Royal V-Belts drive the edger blade on Western Tool & Stamping Company's powerful Edger-trimmer. These belts must withstand oil, dust, weather, and twisting. They must also deliver top performance at many different engine speeds. U.S. Royal V-Belts do the job... were chosen because they outperformed all competitive belts.

VB 104

For every industrial rubber product need, turn to US. For Conveyor Belts, V-Belts, the original PowerGrip "Timing"® Belt, Flexible Couplings, Mountings, Fenders, Hose and Packings... custom-designed rubber products of every description. Discover why U.S. Rubber has become the largest developer and producer of industrial rubber products in the world. See your U.S. Rubber Distributor or contact US directly at Rockefeller Center, New York 20, N. Y.

WORLD'S LARGEST MANUFACTURER OF INDUSTRIAL RUBBER PRODUCTS

United States Rubber

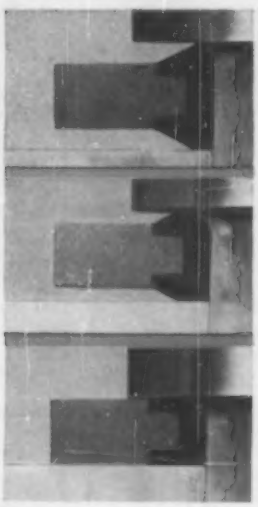
MECHANICAL GOODS DIVISION

Circle 266 on Page 19

Introducing the NEW

Precision Para-seal®

Photographic enlargements show the flow of sealing member under various stages of compression.



New Low Cost Seal
for face to face sealing

This new Precision engineered product reliably and inexpensively seals bolt heads, rivets, screws, flanges and flange fittings. It is priced so low that you can now afford to use a seal of this type in your production equipment.

FEATURES:

- **3 Point Sealing**
- **Self Centering Tongue**
- **Vibration Proof**
- **Controlled Confinement**

For air, water, gases, petroleum products, jet engine fuels, chemicals, etc. —100°F to + 500°F. Send for your free copy of our Brochure describing the features of new Precision PARA-SEAL.

Precision Rubber Products Corporation

"O" Ring and Dyna-seal Specialists

Dept. 431, Oakridge Drive, Dayton 17, Ohio **Canadian plant at: Ste. Thérèse de Blainville, Québec**

Circle 267 on Page 19

Circle 268 on Page 19→

INSTANT ENGINEERING DRAWINGS

FASTER PRINTS MEAN FASTER PRODUCT DEVELOPMENT, FASTER PRODUCTION. Imagine locating a drawing or record in seconds. Imagine having a work-size print in just 8 seconds. All this, and more, can happen when your drawings and records are on microfilm . . . with FILMSORT® Aperture Cards and THERMO-FAX "Filmac" Reader-Printers. This is the way many companies are saving valuable engineering and drafting time, saving the cost of full-size print preparation, saving space, and saving print distribution costs. The cost? Far less than you would expect for such amazing efficiency. Find out now how you, too, can put microfilm to work—get Instant Engineering Drawings when you need them, where you need them—with 3M Microfilm Products.

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Please send me information about Instant Engineering Drawings.

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COMPANY_____

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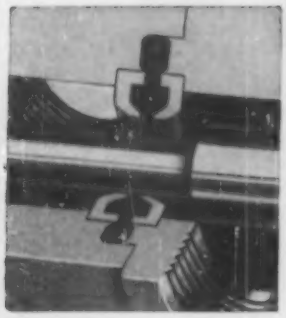
THE TERMS "FILMSORT" AND "THERMO-FAX" ARE REGISTERED TRADEMARKS OF

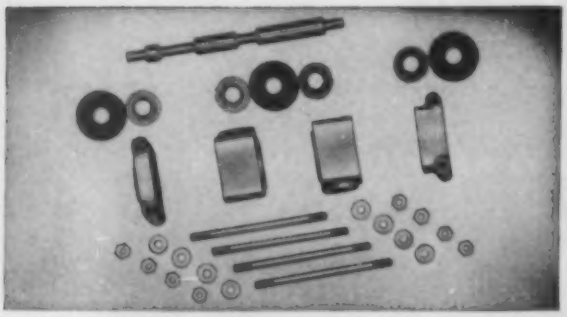
MINNESOTA MINING AND MANUFACTURING COMPANY

. . . WHERE RESEARCH IS THE KEY TO TOMORROW

Do the air valves you buy include these quality features?



SEAL—Exclusive, triple-supported seals permit interference fit of spool for extra-tight closure with minimum wear. Usual damage to conventional "O" rings by moving spool is eliminated.



SIMPLICITY—Uncomplicated parts mean long life and easy servicing. Common parts are used extensively to simplify stocking or repair.

FLEXIBILITY—Modular Construction. Operators, mounting holes and ports may be independently rotated in 90° steps. Operator may be on either or both ends.

This high-quality "D" Pilotair® Valve is available in thousands of combinations. Tailored valves at standard model prices. Nine basic valves may have one or two of eight operators. Many types of spring return or holding functions.

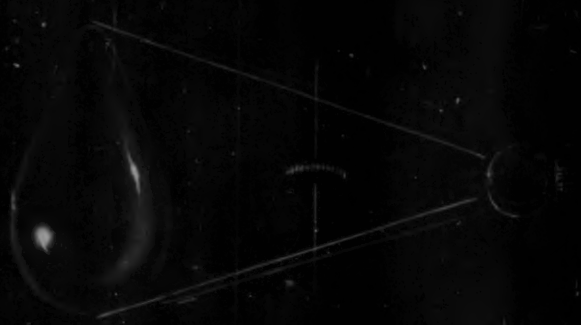
if not, the chances are your maintenance costs are higher than necessary. For more information about quality Fluid Circuitry Controls for trouble-free automation, ask for Catalog A4-75.01.

See the Yellow Pages under Cylinders for the Name of Your Local Distributor, or refer to Sweet's Catalog, Product Design File.

WESTINGHOUSE AIR BRAKE COMPANY

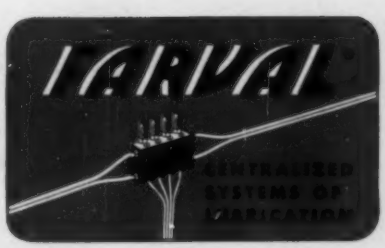
INDUSTRIAL PRODUCTS DIVISION, WILMERDING, PENNSYLVANIA

HERE'S ANOTHER REASON WHY FARVAL IS THE BEST IN CENTRALIZED LUBRICATION



WITH ...
DELIVERY OF EXACT MEASURED
AMOUNTS OF LUBRICANT
TO INDIVIDUAL BEARINGS
IS EASILY ADJUSTED BY
A MERE "TWIST-OF-THE-WRIST"

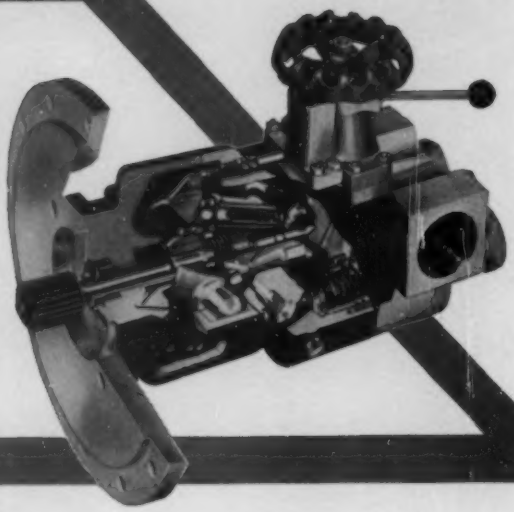
Farval works on time-tested hydraulic principles—does not rely on temperamental springs or unpredictable check valves. Turning down the set screw limits length of piston travel—decreases lubricant delivery. Raising the screw increases delivery. Check with your Farval Representative, today, and see what "Farvalized" equipment can do to boost your profits and production, cut down overhead expense—or write us direct.



Farval Division
Eaton Manufacturing Company
3287 East 80th Street • Cleveland 4, Ohio

Circle 270 on Page 19

Nine piston, variable volume, pressure compensated type IA-38-9 pump, designed for use on Ground Support Equipment.



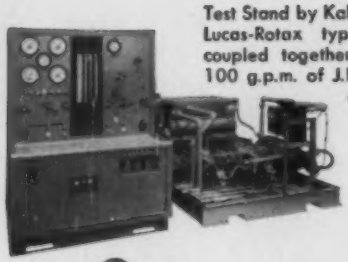
VERSATILITY-PROVEN *lightweight hydraulic* PUMPS AND MOTORS

Well known equipment manufacturers are specifying Lucas-Rotax hydraulic pumps and motors because they offer

- size and weight advantages in the 4 to 104 g.p.m. flow range
- pressures up to 5000 p.s.i.
- low noise level
- other attractive design features

Lucas-Rotax provides full engineering, sales and service throughout North America.

Your hydraulic requirements will be met by contacting Lucas-Rotax Limited, Toronto.



Test Stand by Kahn Company. Three Lucas-Rotax type IP-525 pumps coupled together provide flow of 100 g.p.m. of J.P.4 fuel for testing aircraft equipment.

Marine winches by Timberland-Ellicott are powered by Lucas-Rotax pumps and motors.

Two IA-38 pumps are incorporated in the portable Test Stand by Consolidated Diesel for use in checking out hydraulic system components on fighter aircraft at 5,000 p.s.i.

products of creative engineering by

LUCAS-ROTAX

LIMITED
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6102

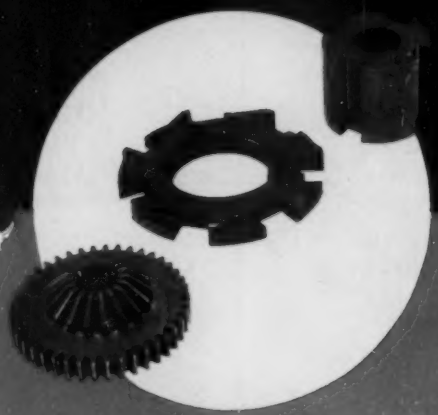
Circle 271 on Page 19

KEYSTONE POWDER METALLURGY PROGRESS

NEW MATERIALS
IMPROVED PROPERTIES

NEW AREAS OF APPLICATION

EXAMPLE: **Keystone C-65 Phosphor Bronze.** Higher tensile strength, higher hardness, good ductility open successful new applications for business machine parts, where conventional sintered bronze alloys fail to meet required service standards.



EXAMPLE: **Keystone Grades Z-23, Z-33.** Here high strength, good heat-treatability and high hardness without copper infiltration make tough rotors and gears for automotive hydraulics in transmission, power steering, etc.

EXAMPLE: **Keystone Grade Z-2.** For the most rugged applications where highest strength is required—like these hydraulic pump gears now being used in farm equipment, industrial trucks, heavy off-highway vehicles and loaders.

	Grade		Composition Per Cent	Apμ. Density Dry gms/cc	Ultimate Tensile Str., PSI	Elongation % in One Inch	Rockwell Hardness Apparent	Remarks
•	Z-23	Copper Steel Alloy	94.0 Fe Min. 1.0-4.0 Cu 2.0 Max. Total other elements	6.2—6.6	60,000	1.0	B-56	A fine iron-base alloy with good strength in the medium density range. Has proved successful in various gear applications when extreme impact is not present.
•	Z-33 Heat-Treated	Carbon Steel Alloy	Fe 95.5 Min. Si .3 Max. Al .2 Max. 3.0 Total other elements	6.1—6.5	70,000	.0 .0	A-40 C-20	Excellent for wear applications especially when Keyonyxed. High apparent hardness accounts for good wear characteristics. Pearlite structure —good heat-treatability.
	Z-2	AISI 4630 Alloy Steel As Hardened	C—.30 N 1.7 Mn—.50 Mo 2.5 Si—.25 Fe Balance	7.2 Min.	160,000	1.5	C-35	The ultimate in properties in modern powder metallurgy. A true alloy steel.
	C-65	Phos. Bronze	Cu 87.0 Min. Sn 9.5—10.5 P .3—.5 Total other elements 1.5 Max.	6.9 Min.	30,000	3.5	H-75	The best properties available in a bronze material. For use in bronze parts where higher strength is required. In strength range of many sintered iron materials.

Write us for full information

Keystone CARBON COMPANY
POWDERED METAL PARTS DIVISION
ST. MARYS, PA.

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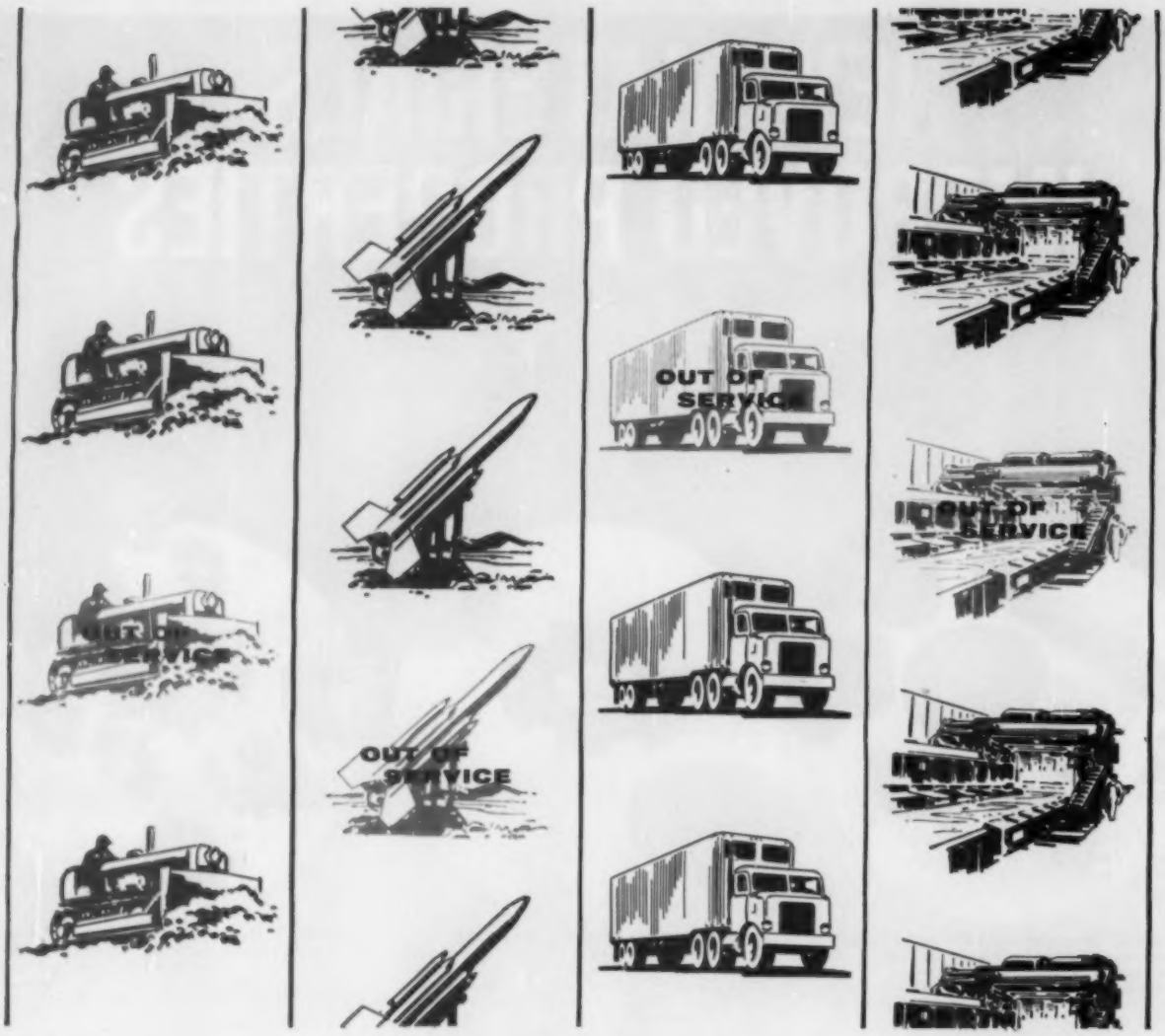

Dependable ROLLWAY BEARINGS

help keep your down-time low

When a bearing "goes", your machine stops.

That's why it pays to call in Rollway. Especially when reliability is a must.

At Rollway, you can choose from a wide selection of sizes and types with maximum capacities . . . for normal, low or high temperature operation. All meeting or exceeding RBEC requisites in Classes 1 to 5.

You'll find that Rollway meets your needs exactly – in commercial grade, precision, or ultra-precision bearings. To get the bearing you want in a hurry, or to start R and D on the bearing you've been dreaming about, just call or write Rollway Bearing Company, Inc., Syracuse 1, New York.

Where So Much Depends on So Little . . . You can depend on

ROLLWAY BEARINGS

Radial and Thrust Cylindrical Roller Bearings

Circle 273 on Page 19

Think Service . . .

HOLO-KROME REPRESENTATIVES ARE READY TO HELP YOU DESIGN AND MANUFACTURE FOR GREATER PROFIT

To take advantage of the special knowledge that's available to you, call a Holo-Krome representative. He's an expert on top-quality THERMO-FORGED* socket screws and is skilled in all phases of applying them. He'll help you design the best fastener into your product in a way that will keep manufacturing costs at a minimum.

Application assistance, same-day service and cost-reducing quality make Holo-Krome THERMO-FORGED socket screws your best fastener buy. Like full details on how Holo-Krome quality and service can help increase your profit? See your authorized Holo-Krome distributor, or write for more information.

**Trade Mark of The Holo-Krome Screw Corporation*

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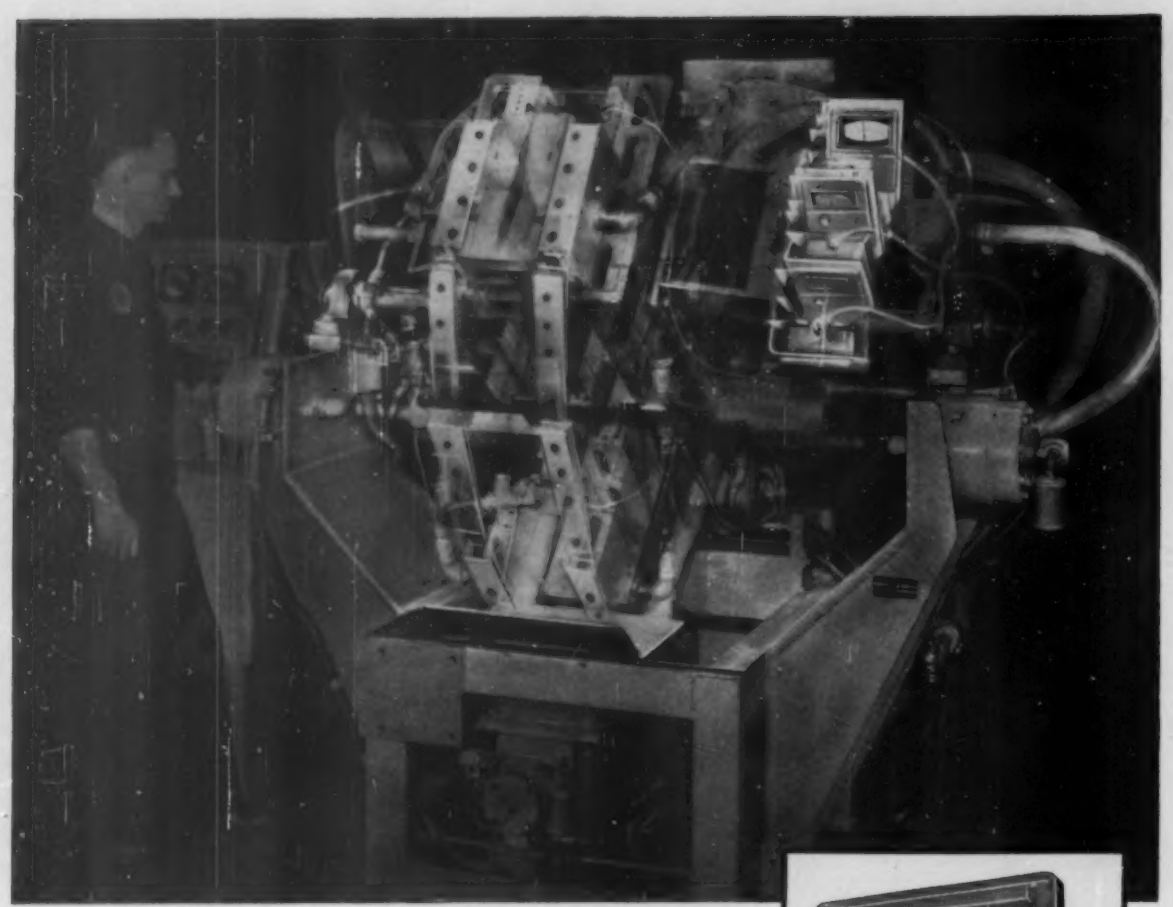
SOCKET SCREWS

SOLD ONLY THROUGH AUTHORIZED HOLO-KROME DISTRIBUTORS
THE HOLO-KROME SCREW CORPORATION • HARTFORD 10, CONN.

Circle 274 on Page 19



A Partlow Model MFS indicating controller is shown in action in this "multiple exposure" shot of a Hole-Core Automatic Molding Machine manufactured by Spo, Inc., Cleveland, Ohio.

The Temperature Control Built to

SHRUG OFF SHOCK

2438 Times a Day

Every working day, the Partlow Temperature Control in this photo takes between 2400 and 2500 solid "roundhouse punches" from the shell-molding machine to which it is attached.

But despite jarring shock and vibration, and a constant barrage of foundry dust, the Partlow goes right on delivering precision control—without letup or breakdown.

Actually, only a control as simple and rock-solid as the Partlow could withstand this kind of punishment! Because only the Partlow contains no hairsprings, or delicate gadgets.

All Partlow thermal elements of the same range are interchangeable *on the job*, too. There's no time lost waiting for your control to come back from the factory. And you get this extra margin of dependability *without loss of accuracy*. Partlow controls are precise to within 1% of scale in any one of 10 ranges from –30° to 1100° F.

If you use or manufacture equipment within this temperature range, there's a Partlow to fit your application exactly . . . and save you money, too. Available in Pneumatic, Electric or Self-Contained Gas types, in recording, indicating or non-indicating models! To field test any Partlow control . . . or to obtain full details write, The Partlow Corporation, New Hartford, N. Y. Dept. D-1261.

Export Ad. Auriema, Inc., 85 Broad St., New York 4, N. Y.

A complete absence of gadgets and superfluous parts, as seen in this open view of the new MFS indicating control, explains the Partlow's unique ability to function accurately even under the most severe operating conditions.

You can pay more but you can't buy better than

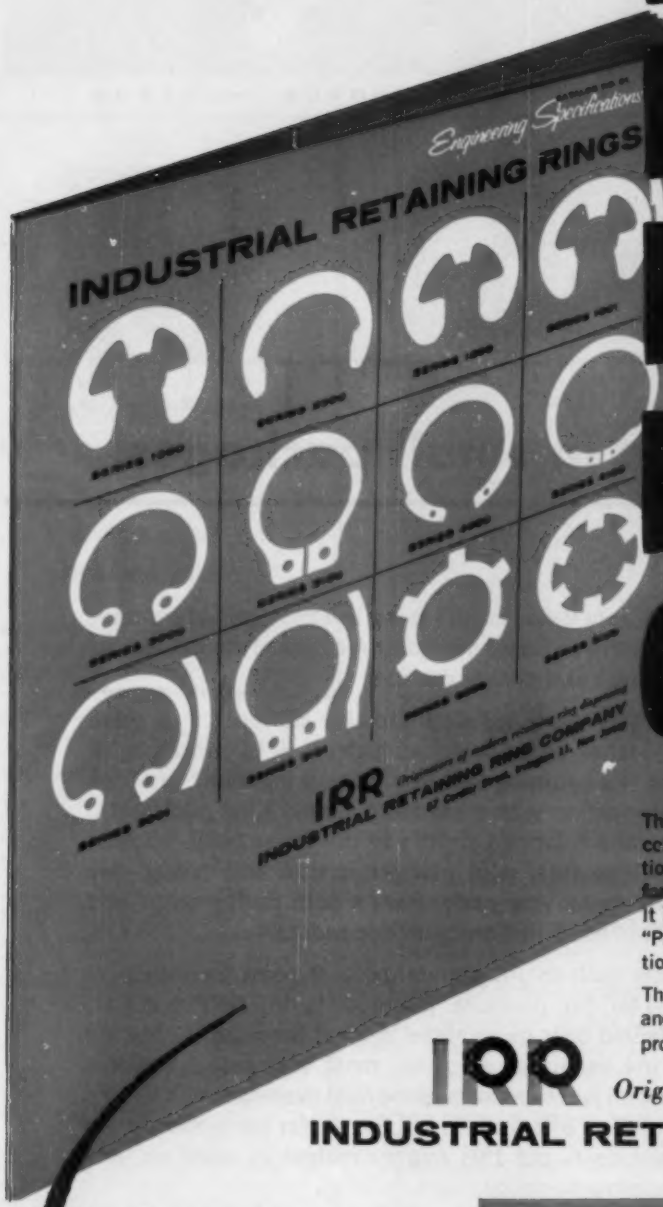
PARTLOW

TEMPERATURE CONTROLS

Circle 275 on Page 19

For YOUR File . . .

New! Industrial Retaining Ring Catalog



This new Industrial Retaining Ring Catalog, No. 61, contains complete information and engineering specifications on IRR Internal and External Retaining Rings—both for axial and radial assembly—from sizes .040" to 4.125". It also has information of the exclusive, time-saving, IRR "PRE-STACKED" Axial Assembly Rings as well as information on IRR Pliers and Accessories.

The Industrial Retaining Ring Catalog is easy to work with and from. It will greatly assist in design, purchasing and production.

IRR *Originators of modern retaining ring dispensing*

INDUSTRIAL RETAINING RING COMPANY

57 Cordier Street, Irvington 11, New Jersey

Use for FREE Samples and Catalog

INDUSTRIAL RETAINING RING COMPANY
57 Cordier Street, Irvington 11, N. J.

Please, send me samples of Industrial Retaining Rings and the new IRR Catalog No. 61.

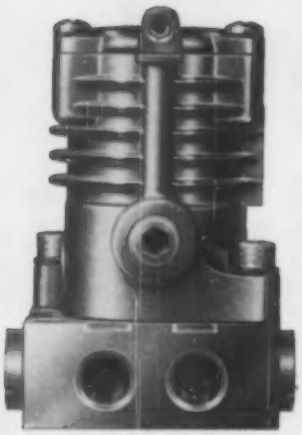
Name ..... Title .....

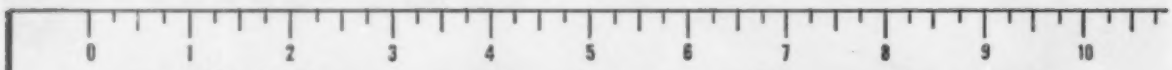
Company .....

Street .....

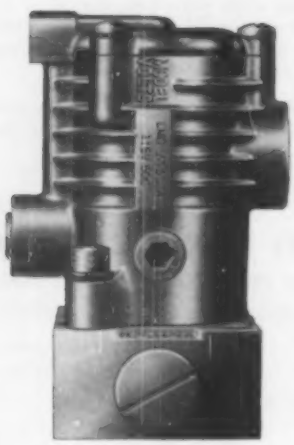
City ..... Zone ..... State .....

Circle 276 on Page 19





good things come in small packages!



Especially Valvair's Mini-King low-cost, miniature four-way valve . . . ideal for control of small double-acting cylinders and similar devices!

Valvair's Mini-King is remarkably compact . . . a mere 2⅞ inches wide—4 inches high . . . 37½ ounces light! And, it's lightning fast, too. Valvair ingenuity provides 4-way action with a standard Speed King pilot and a pressure-balanced shuttle in the lower body. Shuttle, stainless steel pilot plunger, piston and spring—are the only moving parts. Here's both performance and built-in multi-million cycle dependability!

Pilots built to JIC standards . . . 2 point mounting . . . 15-140 psi pressure range . . . ¼ in. NPT ports . . . solenoid coils guaranteed against burn-out for the life of the valve, for ac or dc, most voltages . . . optional integral junction box and manual over-ride . . . Valvair's Mini-King offers them all! For better performance—at lower cost—put this mighty midget to work on your equipment—soon!

Ask your nearby Bellows-Valvair Field Engineer to show you the Mini-King today. Or, write for Bulletin SVA-1. Address Bellows-Valvair, Akron 9, Ohio, Dept. MD-1261.

Bellows-Valvair

AKRON 9, OHIO

DIVISION OF INTERNATIONAL BASIC ECONOMY CORPORATION (IBEC)

8123

RB&W FASTENER BRIEFS

RUSSELL, BURDSALL & WARD BOLT AND NUT COMPANY

Technical-ities

by Fred E. Graves

A word about bolt load levels

If you tighten a bolt beyond its proportional limit it deforms plastically. Materials' engineers call the stress where this permanent set is measurable the bolt's yield strength.

NO HARM IN OVERTIGHTENING

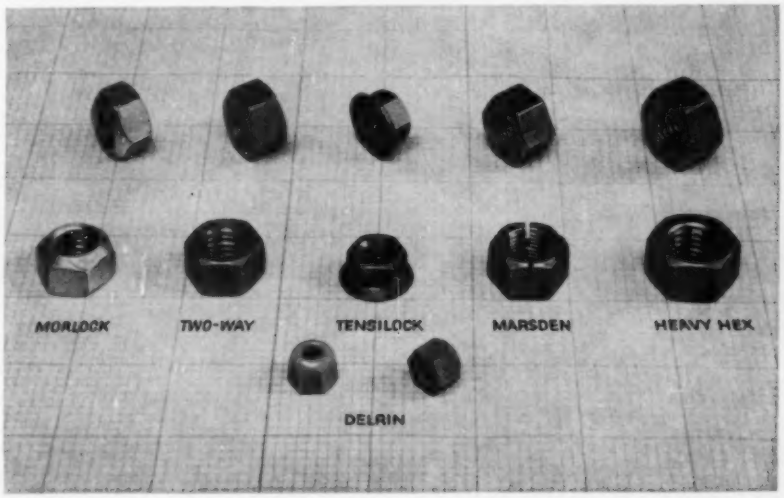
You can tighten up to yield strength—and even beyond. Where permanent connections are made this is recommended.

Naturally, pitch of the external threads increases as a screw stretches. Conversely, because a nut undergoes compression the pitch of its internal threads decreases.

This results in a cumulative off-lead condition. In most instances, it's not practical to re-use a bolt stressed beyond its elastic limit.

For the usual type of solid joints, the recommended stress level for SAE Grade 2 fasteners is 40,000 psi; for Grade 5 (high strength), it's 60,000 psi. While below yield strength, these levels provide high bolt preload—good assurance against loosening and fatigue.

Always specify that the assembler torque a bolt or screw to the recommended level. It's the usable 'muscle' you pay for in fasteners. If you don't use it, chances are somebody's money is being wasted. Equally important, *the joint isn't as strong as it could be.*



How to keep a nut in its place

LOCKING nuts are used to develop clamping force on a vital joint . . . or, to restrict 'end play' of movable members.

Self-locking action can be achieved by: 1) increasing thread friction, or 2) an anchoring mechanism. Examples:

PREVAILING-TORQUE LOCKING

1. Morlok® nut. Crown is processed to change phase of last thread. Hence the Morlock nut screws on easily until its last thread engages; then more on-torque must be used. Off-torque is correspondingly high. It locks anywhere on the screw.

2. Two-way locknut. Depressions staked in two opposite faces deform center thread slightly for self-locking action. Double-chamfered, it goes on from either end, speeding assembly.

3. Delrin* locknut. This metal-like plastic locknut forms its own threads. Available for light duty in #10 and 1/4" sizes, it has holding strength of 400-700 pounds, prevailing torque of 7-15 in-lbs, stripping torque of 15-25 in-lbs, depending on size. They're reusable.

HIGH THREAD TENSION LOCKING

4. Tensilock® nut. Carburized teeth bite into bearing surface, resist counter-clockwise rotation. Combining clamping with anchoring action, it requires 25% more off-torque than on-torque to loosen.

5. Marsden® nut. When torqued snug, slotted sides of this nut draw inward against screw's threads, thus creating a frictional 'bind.' Nut is capable of high clamping force too.

6. Heavy hex nut. Engineers often overlook locking action inherent in this nut. Used with high-strength screws, it develops high thread tension and a corresponding high friction on thread flanks. This not only means a stronger joint, but one that won't shake loose.

These and other lock nuts are manufactured by RB&W. Write for specific recommendations on your design problem. Russell, Burdsall & Ward Bolt and Nut Co., Port Chester, N. Y.

*Du Pont trademark.

Plants at: Port Chester, N. Y.; Coraopolis, Pa.; Rock Falls, Ill.; Los Angeles, Calif. **Additional sales offices at:** Ardmore (Phila.), Pa.; Pittsburgh; Detroit; Chicago; Dallas; San Francisco.

Circle 278 on Page 19

Post-Forming: New Way to Bigger Savings with Malleable Castings

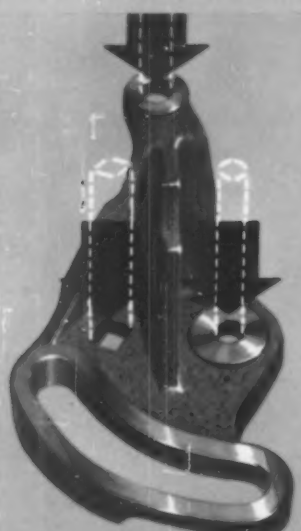
The ductility of Malleable iron castings permits use of high-speed forming techniques to finish Malleable parts at lower cost. Take advantage of the versatility you get only with ferritic and pearlitic Malleable castings. For a fuller understanding of how Malleable can help you, call any producer that displays this symbol —

Free Folder describing these techniques is available for your use. Just ask any member of the Malleable Castings Council for Data Unit No. 116, or write to Malleable Castings Council, Union Commerce Building, Cleveland 14, Ohio.

MEMBER
MALLEABLE
CASTINGS COUNCIL

Hot Form It — Hot coining this Malleable transmission part reduces finished cost . . . eliminates three cutting operations required by the previously used steel part.

Roll It — Oil grooves in lawnmower crankshafts and splines in compressor crankshafts are just two of many places where rolling proves more economical than machining.



Punch It — Holes with diameters greater than the thickness of the metal can be punched in Malleable. Two round holes and a square hole are punched simultaneously in this idler arm.

Spin It — Malleable's ductility permits the sleeve and end disc in this ball joint to be held in place by spinning the Malleable housing into a strong, permanent flange.

MALLEABLE

Get the most for your metals dollar...get

CONNECTICUT
Connecticut Mall. Castings Co., New Haven 6
Alloy Foundries Division,
The Eastern Co., Naugatuck

ILLINOIS
Central Fdry. Div., Gen. Motors, Danville
Chicago Malleable Castings Co., Chicago 43
Moline Iron Works, Moline
Moline Malleable Iron Co., St. Charles
National Castings Co., Cicero 50
Peoria Malleable Castings Co., Peoria 1
Wagner Castings Company, Decatur

INDIANA
Albion Malleable Iron Company,
Muncie Division, Muncie
Link-Belt Company, Indianapolis 6
National Castings Co., Indianapolis 22

IOWA
Iowa Malleable Iron Co., Fairfield

MASSACHUSETTS
Belcher Malleable Iron Co., Easton

MICHIGAN
Albion Malleable Iron Co., Albion
Auto Specialties Mfg. Co., Saint Joseph
Cadillac Malleable Iron Co., Cadillac
Central Fdry. Div., Gen. Motors, Saginaw

MINNESOTA
Northern Malleable Iron Co., St. Paul 6

MISSISSIPPI
Mississippi Malleable Iron Co., Meridian

NEW HAMPSHIRE
Laconia Malleable Iron Co., Laconia

NEW YORK
Acme Steel & Mall. Iron Works, Buffalo 7
Frazer & Jones Company Division
Eastern Malleable Iron Co., Solvay
Oriskany Malleable Iron Co., Inc., Oriskany
Westmoreland Mall. Iron Co., Westmoreland

OHIO
American Malleable Castings Co., Marion
Central Fdry. Div., Gen. Motors, Defiance
Dayton Mall. Iron Co., Ironton Div., Ironton
Dayton Mall. Iron Co., Ohio Mall. Div.,
Columbus 16
National Castings Co., Cleveland 6

PENNSYLVANIA
Buck Iron Company, Inc., Philadelphia 22
Erie Malleable Iron Co., Erie
Lancaster Malleable Castings Co., Lancaster
Lehigh Foundries Company, Easton
Meadville Malleable Iron Co., Meadville
Pennsylvania Malleable Iron Corp., Lancaster

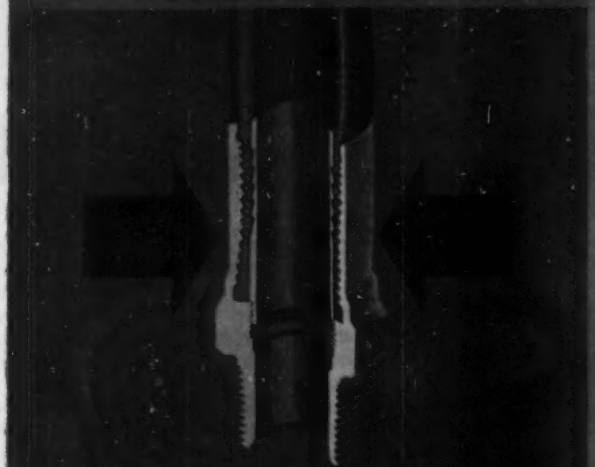
TEXAS
Texas Foundries, Inc., Lufkin

WEST VIRGINIA
West Virginia Mall. Iron Co., Point Pleasant

WISCONSIN
Belle City Malleable Iron Co., Racine
Chain Belt Company, Milwaukee 1
Federal Malleable Company, Inc.,
West Allis 14
Kirsh Foundry Inc., Beaver Dam
Lakeside Malleable Castings Co., Racine
Milwaukee Malleable & Grey Iron Works,
Milwaukee 46

Bend It — A 30% cost reduction was achieved by casting this Malleable iron twine finger flat . . . then bending the arm about 25 degrees and coining the center hub in one fast, post-forming operation.

Coin It — Very close tolerances are often met economically by either cold or hot coining. The head of this T-bolt is coined to meet tolerances of ± .005" on its .475" width without any machining.



Harden It — Surface hardness values in excess of 55 Rockwell C can be achieved with pearlitic Malleable by either flame or induction hardening. Response is excellent, and results are uniform.

Standard Forge & Axle Co. forges 5-inch by ½-inch Pittsburgh Seamless Mechanical Tube ends down to 2⅝" solid steel wheel spindle ends (cross section above). The Montgomery, Ala., plant then machines and grinds bearing surfaces to .0005-inch tolerance to produce single-piece, 20,000 pound capacity trailer axles. Trailer operators benefit from higher payloads because . . .

They Throw Away The Holes—And Save Weight

The trick in making a seamless steel tube is piercing a hole in a round of solid steel.

But Pittsburgh Steel Company's Seamless Steel Mechanical Tubing makes the full circle in production of trailer axles at Standard Forge & Axle Co., Montgomery, Ala.

Standard, in effect, throws away the holes by forging the tube ends down to solid steel again, leaving only a hollow steel center and spindle section.

The result: a lightweight, one-piece trailer axle made entirely from a single length of seamless tube—including load bearing wheel spindles, precision ground for bearing and seal seats.

The advantage: assured strength and safety of seamless steel, plus, for example, reduced axle weight for trailer operators in a 20,000 pound capacity axle.

Starting with a seamless steel tube 5" x ½" x 87⅛" for this particular axle, Standard upsets both ends, then swages them down to the shape of a spindle with a 2⅝" solid end.

That's deformation of the roughest kind.

But Pittsburgh Seamless Mechanical Tubing takes it in stride, then bounces back under heat treatment with the physical properties required for precision finishing of the critical spindle surfaces, and the toughness necessary for a long life in hard service.

And that kind of performance takes seamless steel tubes with exceptional internal soundness, consistent grain structure, and chemical and dimensional uniformity.

Pittsburgh C-1040 grade Seamless Mechanical Tubing supplies these properties consistently—for this type

After upset, Pittsburgh Seamless Mechanical Tubes, with 5-inch OD and ½-inch wall, are swaged to solid steel spindle shape on drop forge, at right. Standard's heat treating process refines grain, restores toughness of steel.

Standard also produces high-strength inserted spindle trailer axle by inserting forged alloy steel spindle with 4.065-inch OD into 4.040-inch burnished ID of 5-inch seamless steel tube under 50,000-pounds pressure.

Standard Forge & Axle Sales Manager James A. Rumbley says Pittsburgh Steel Company, as longtime major supplier of seamless mechanical tubes, "leaves nothing to be desired in product or service."

axle and for Standard's high-strength inserted spindle type.

James A. Rumbley, Standard's sales manager, says:

"Trailer axles are high-weight carrying members subject to tremendous load shocks. So we use the finest materials available to assure our customers trouble-free service. Seamless steel mechanical tubes help us to do that, with complete safety and at less weight.

"For many years, Pittsburgh Steel Company has been one of our major tubing suppliers. It has left nothing to be desired either in product or service."

That's standard practice with Pittsburgh Steel—whether supplying seamless mechanical tubing to Standard's specific requirements, or to yours. Be certain with Pittsburgh Seamless. Contact one of the district offices listed below.

Pittsburgh Steel Company

Grant Building • Pittsburgh 30, Pa.

DISTRICT SALES OFFICES

Atlanta	Cleveland	Dayton	Los Angeles	Pittsburgh
Chicago	Dallas	Detroit	New York	Tulsa
		Houston	Philadelphia	Warren, Ohio

Circle 280 on Page 19

solve the processing puzzle WITH EASTERN CENTRIFUGAL PUMPS

In every detail of size, weight, space requirements, materials, power and costs, Eastern Centrifugal Pumps are made to match strict process requirements.

- **PRESSURES:** to 21 psi in single stage pumps; to 70 psi in multi-stage types
- **FLOWS:** capacities to 70 gpm in single-stage pumps, to 10 gpm for many multi-stage models
- **MOTORS:** standard motors for 115/230-volts 60 cycles 1 phase (other electrical characteristics available). Power range from ⅛ to 1½ H.P.
- **ENCLOSURES:** drip-proof, totally enclosed, and explosion-proof ball-bearing frames
- **DRIVES:** all models available in belt or coupling drive with ball-bearing equipped stands. Space-saving close-coupled pumps most rugged and popular — but many pedestal models also available
- **SEALS:** a variety of rotary seals and stuffing boxes, to fit every application
- **METALS:** your option of cast iron, bronze, stainless steel (18-8 type 303 and 316) Monel, Cast Iron, Hastelloy "C"
- **INSTALLATIONS:** a wide range of transfer, recirculation, feed, boost, and filter-pumping applications

TO FIND OUT: write for the brand-new Centrifugal Pump Catalog — Bulletin 130. Here are all the models — including useful engineering data.

For a complete review of positive displacement pumps for non-lubricating fluids, write for Bulletin 220. Eastern Bulletin 400 is your guide to a broad line of midget-centrifugal pumps and stirrers for the laboratory.

EASTERN INDUSTRIES PUMP DIVISION

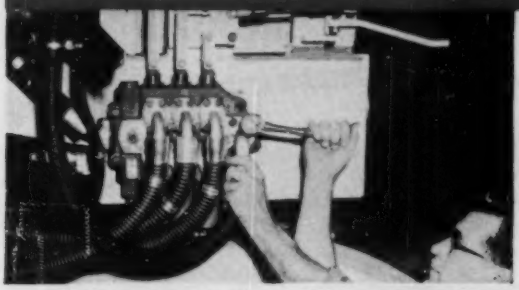
EASTERN INDUSTRIES, INCORPORATED

100 SKIFF STREET • HAMDEN, CONNECTICUT
West Coast Office: 4203 Spencer St. • Torrance, Calif.

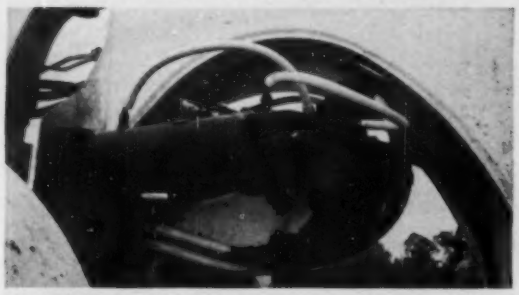
Other Eastern products: • hydraulic motors • gear pumps • positive displacement pumps • aircraft pumps

Circle 281 on Page 19

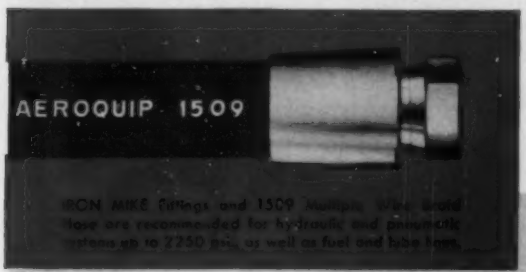
New Aeroquip Fitting Wins Place on Major Equipment



IRON MIKE Fittings are installed on the production line in the plant of a major construction equipment manufacturer.



Checked after lengthy field service, Aeroquip Hose Lines with IRON MIKE Fittings proved they could withstand the most punishing tests.



IRON MIKE

T.M.

NEW, LOW-COST REUSABLE FITTING PROVEN DEPENDABLE

Exhaustive field testing proved to one major equipment manufacturer that Aeroquip's new IRON MIKE Fitting meets their requirements best for high pressure hose lines. It combines the rugged dependability and field service advantages of a reusable fitting with the low initial cost of a non-reusable fitting.

This manufacturer is now standardizing on Aeroquip High Pressure Hose and IRON MIKE Fittings for heavy-duty hydraulic lines on all of its equipment.

IRON MIKE Fittings are now available for hose sizes from ¾" to 2" I. D., in ten standard end styles to meet a wide range of equipment applications. For full details, return the coupon below.

PATENT APPLIED FOR

Aeroquip

AEROQUIP CORPORATION • JACKSON, MICHIGAN
INDUSTRIAL DIVISION
INDUSTRIAL PLANTS: VAN WERT, OHIO; BURBANK, CALIFORNIA; DALLAS, TEXAS; PORTLAND, OREGON; CRANBURY, NEW JERSEY
In Canada: Aeroquip (Canada) Ltd., Toronto 19, Ontario
In Germany: Aeroquip G.m.b.H., Baden Baden-Oos
AEROQUIP PRODUCTS ARE PROTECTED BY PATENTS IN U.S.A., CANADA AND ABROAD

Aeroquip Corporation, Jackson, Michigan MD-12
Please send me Bulletin 651 on new IRON MIKE Fittings.

Name_____

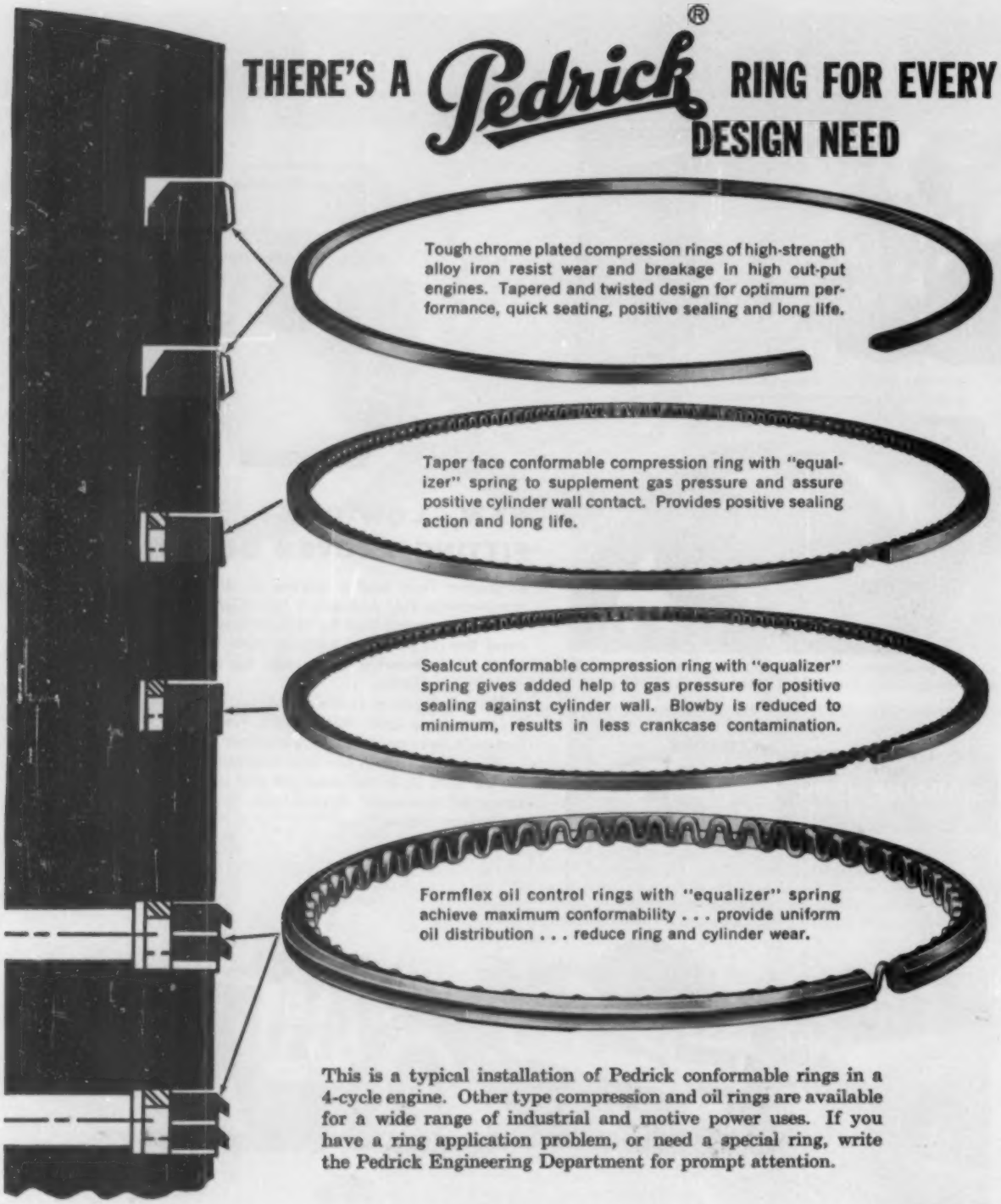
Title_____

Company_____

Address_____

City_____ Zone_____ State_____

THERE'S A *Pedrick*® RING FOR EVERY DESIGN NEED



Tough chrome plated compression rings of high-strength alloy iron resist wear and breakage in high out-put engines. Tapered and twisted design for optimum performance, quick seating, positive sealing and long life.

Taper face conformable compression ring with "equalizer" spring to supplement gas pressure and assure positive cylinder wall contact. Provides positive sealing action and long life.

Sealcut conformable compression ring with "equalizer" spring gives added help to gas pressure for positive sealing against cylinder wall. Blowby is reduced to minimum, results in less crankcase contamination.

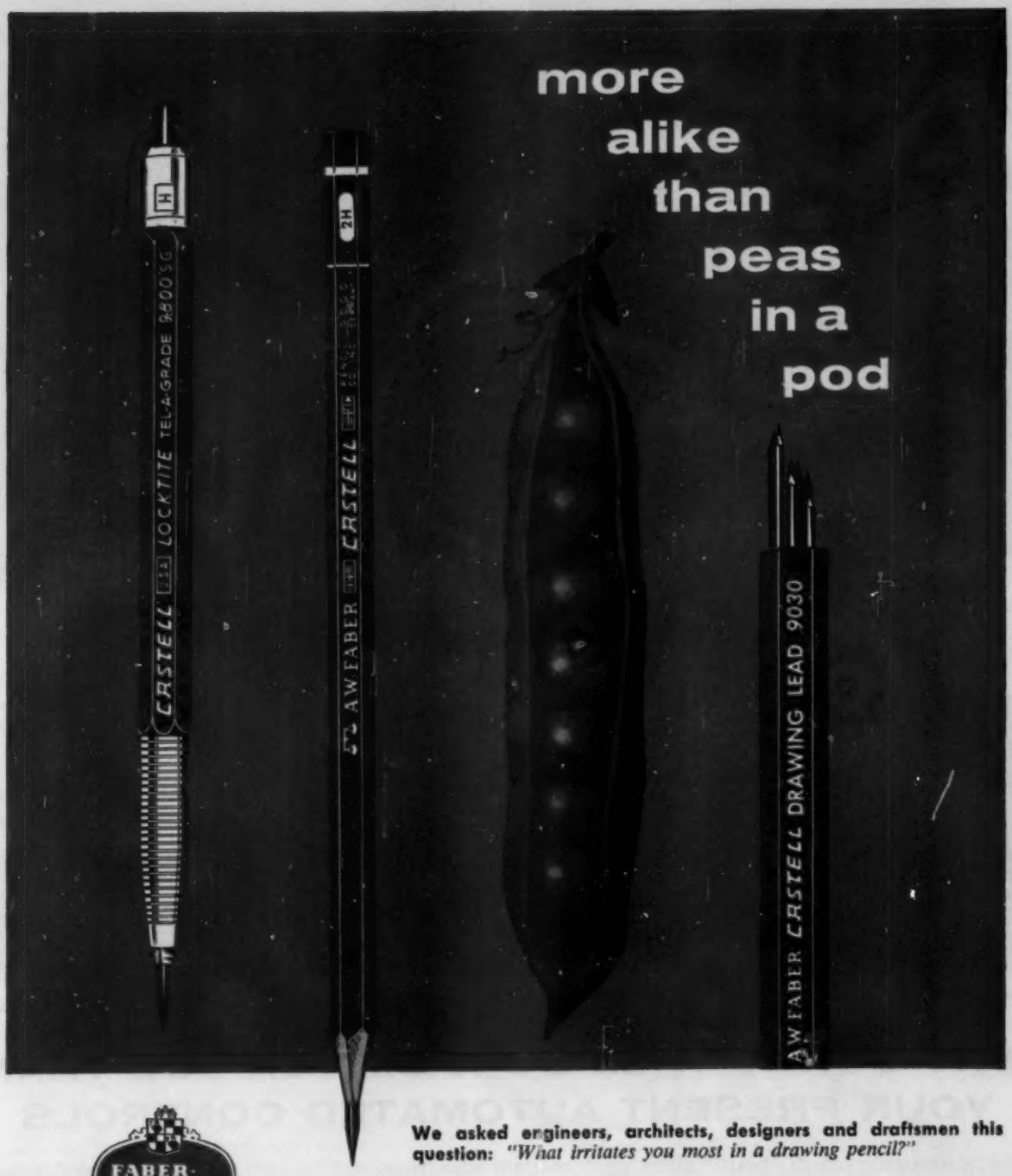
Formflex oil control rings with "equalizer" spring achieve maximum conformability . . . provide uniform oil distribution . . . reduce ring and cylinder wear.

This is a typical installation of Pedrick conformable rings in a 4-cycle engine. Other type compression and oil rings are available for a wide range of industrial and motive power uses. If you have a ring application problem, or need a special ring, write the Pedrick Engineering Department for prompt attention.

ENGINE PARTS DIVISION
GOULD-NATIONAL
BATTERIES, INC.
St. Paul 1, Minnesota
Superior-Arrowhead is a trademark of Gould-National Batteries, Inc.

Manufacturers of Pedrick rings; Superior-Arrowhead, White, Gillett & Eaton pistons; cylinder assemblies; oil, air and fuel filters. Iron and aluminum casting facilities available.

Circle 283 on Page 19



We asked engineers, architects, designers and draftsmen this question: *"What irritates you most in a drawing pencil?"*

Many of them said, *"A degree that suddenly changes its character. You start your drawing with a 2H. When it wears out, you reach for another 2H — but this one draws like a 3H."*

This can never happen with CASTELL. Its grading is so rigidly controlled, you can go back to your unfinished drawing months — or even *years* — later, without any perceptible change in line or color. It produces the same image density and sharpness of detail. No peas in a pod can match the consistent uniformity of CASTELL'S superb 20 degrees, 8B to 10H. Draws perfectly on all surfaces, including CRONAR and MYLAR base films. Join the masters of *your* profession. Buy CASTELL, call your dealer today.

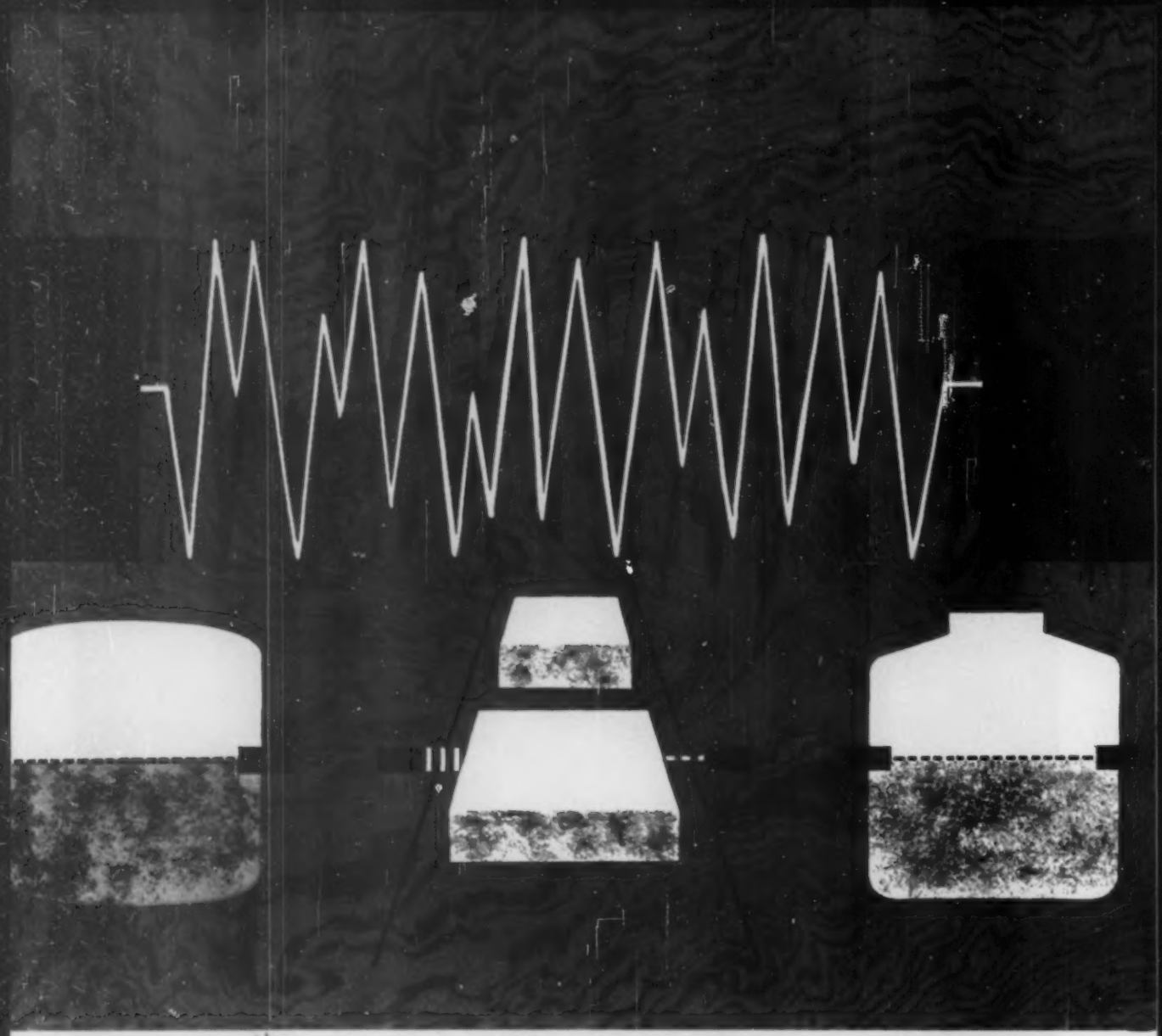
FABER-CASTELL

A.W.FABER-CASTELL
Pencil Co., Inc., Newark 3, N. J.

Our Bicentennial year—1761-1961
200 years of uninterrupted
manufacturing experience.

***#9800 SG Locktite Tel-A-Grade** Lead Holder with no-slip, functional grip that's kind to tired fingers ■ Bull dog clutch ■ Unique degree indicator ■ Carries 2-year guarantee ■ **Castell Drawing Leads #9030,** identical in grade and quality with world-famous Castell drawing pencil ■ Usable in all standard holders, but perfect for Locktite ■ 7B to 10H, and a kaleidoscope of colors ■*

Circle 284 on Page 19



LIQUID LEVEL CONTROL NON-CONTACT SENSING AND SWITCHING DRY LEVEL CONTROL

WHY SONAC WILL DO A BETTER JOB THAN YOUR PRESENT AUTOMATED CONTROLS

Sonac's ultrasonic energy "beam" offers you important advantages over present controls. Its transistorized circuit assures low maintenance and long life in even the most severe environments. Sonac sensors are not affected by vibration, dust, smoke, steam, contamination, or too much or too little light. Level controls are not sensitive to viscosity, specific gravity, foam or the electrical characteristics of the material. ☐ Hermetically sealed sensors operate in temperatures from −325°F to +450°F. They withstand pressures to 2000 psi. What can Sonac do for you? Send for complete descriptive booklet.

DELAVAN Manufacturing Company

WEST DES MOINES, IOWA

Canadian Representative: KNOWLES & FOSTER (North America) Ltd., 708 Terminal Bldg., Toronto 1, Ontario, Canada

Circle 285 on Page 19

engineered problem solvers

A+ FELT PRECISION FABRICATED PARTS

ADD the benefits of our diversified fabricating techniques to the world's most versatile engineering and design material . . . A+ Felt . . . in a complete selection of wool and synthetic fibers . . . manufactured, impregnated, coated or treated to meet your special requirements . . . AND GET: One-source responsibility, assuring economical solutions to your engineering and design problems.

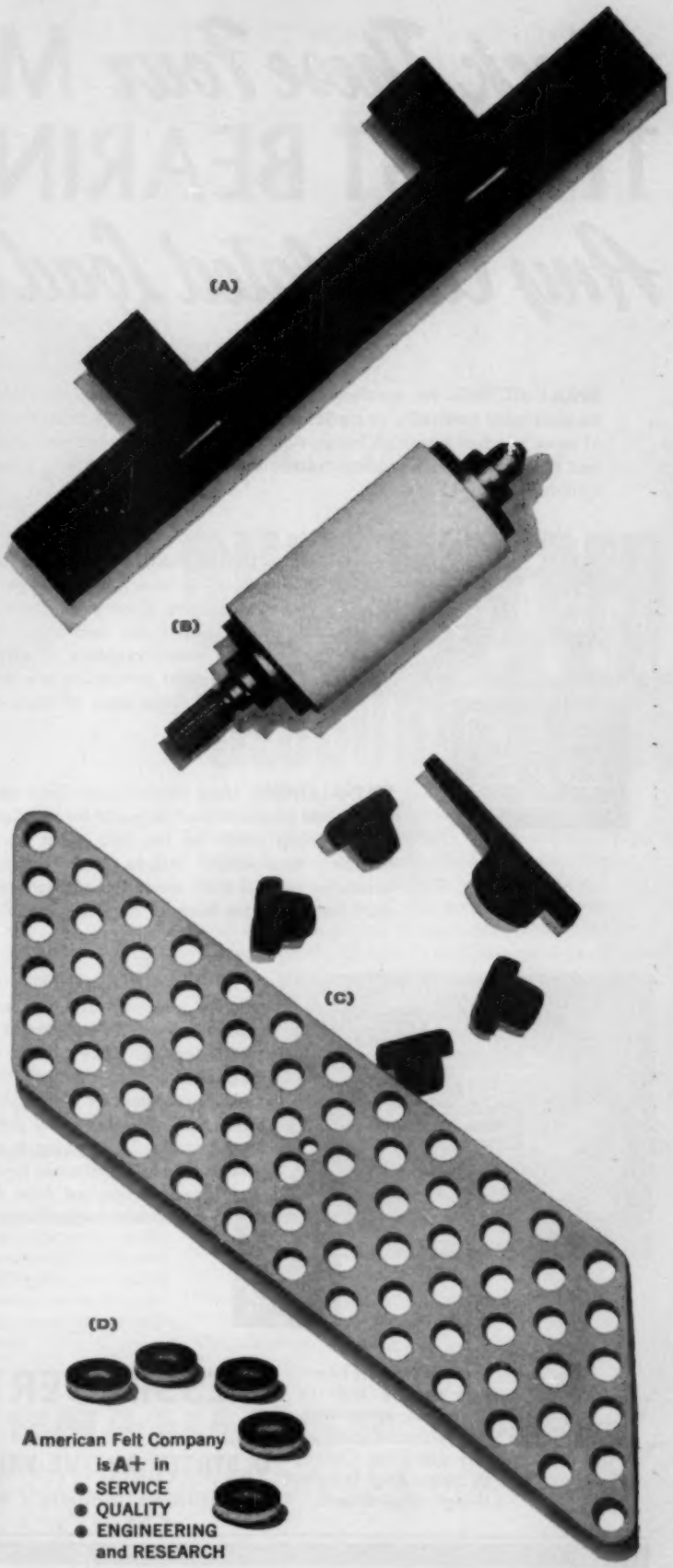
Our fabricating techniques include:

MACHINING
MOLDING
SKIVING
STRIPPING and STAPLING: **(A)** A+ Felt oil wick lubricator designed by AFCO engineers.
SHAPING
EXTRUDING
GRINDING: **(B)** A+ Felt ink roller.
CEMENTING
GROMMETING
DIE CUTTING: **(C)** A+ Felt electric motor wicks; keyboard cushion.
PERFORATING
DRILLING
LAMINATING: **(D)** A+ Felt and rubber laminated oil seals.
STITCHING

RAPID SERVICE . . . from our nationwide precision fabricating facilities located at Glenville, Connecticut; Detroit; San Francisco and Los Angeles . . . serving you with A+ Precision Fabricated Felt Parts and also parts custom fabricated by us from all types of engineering materials. Send us your specifications and requirements, for our quotation. Our Engineering and Research Division, backed by over 60 years of experience, is ready to assist you in selecting or developing a material suited to your needs.

SEND FOR Technical Bulletins on the properties of A+ Wool Felts and FEUTRON® Synthetic Fiber Felts.

American Felt Company
[illegible] Glenville Road Glenville, Connecticut

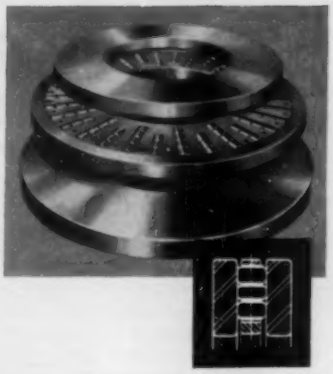


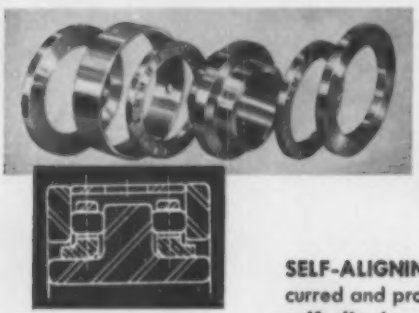
American Felt Company is A+ in
- SERVICE
- QUALITY
- ENGINEERING and RESEARCH

Circle 286 on Page 19

Check These Four MESSINGER THRUST BEARINGS *Against Any Calculated Load Requirement*

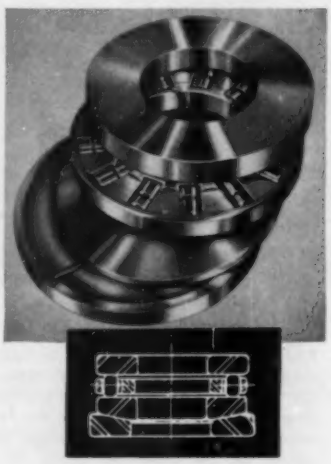
SINGLE-ACTING. For installations where heavy thrust loads are applied. May be positioned **vertically or horizontally.** Will carry 3 to 4 times the thrust load of same size ball bearings. For steel mill and paper mill equipment, large cranes and crane hooks, rock crushers, vertical motors, pumps, etc. Sizes from 3" bore to diameters of 15 feet.





DOUBLE-ACTING. For installations involving heavy thrust loads in **two directions.** Used extensively in steel mill, paper mill and other applications where economy of initial cost and longer service life are important factors. Sizes from 4" bore to over 50" bore.

SELF-ALIGNING. Used where heavy thrust loading is incurred and provision must be made for misalignment. The **self-aligning** action of this bearing is accurate and reliable. Applications include dam gates, grinding machines, vertical shaft electric generators and vertical shaft beaters. Sizes from 4" bore to over 30" bore.



"X" BEARING. Versatility and enduring accuracy are two important advantages of the Messinger Patented "X" Bearing. Takes thrust load in **either direction,** with radial load and overturning moment if necessary all at one time. It is frequently possible to use just one "X" Bearing in place of several bearings of other types. Sizes range upward from 4" bore. Broadest range of applications.

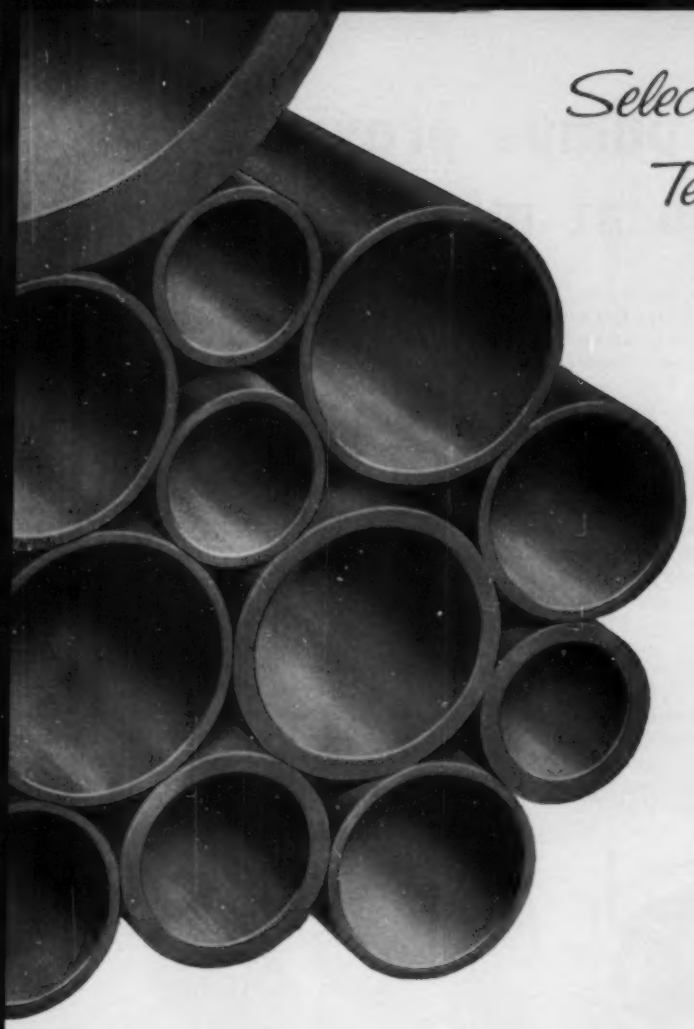
These Messinger bearings can be built to carry exceptionally heavy thrust loads for any size bore. Consult us regarding specific design requirements.

MESSINGER BEARINGS, Inc.

ROLLER AND BALL BEARINGS — *FEATHERWEIGHT TO HEAVYWEIGHT*

D STREET ABOVE ERIE AVE. • PHILADELPHIA 24, PA.

"Smoothing Industry's Pathway for Nearly Half a Century"



Selection of finest raw materials

Testing every step of the way

Inspection to rigid standards

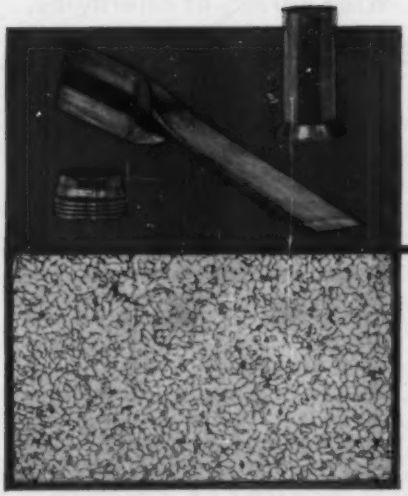
Assure 100% dependability for

OHIO WELDED PRESSURE TUBING

You can be sure — doubly sure — of utmost tubing dependability when you specify Ohio Welded Pressure Tubing — *made by Ohio Seamless.* First, Ohio works to accepted industry standards — ASTM, ASME, and similar Federal and military specifications covering welded pressure tubing. Second, Ohio Welded Pressure Tubing is produced under a *continuous* process of quality control — not just a final test inspection to cull questionable material.

Carefully selected prime raw material is slit, edged, shaped and electric resistance welded on the most versatile and modern equipment in operation. At each and every step of the way Ohio Welded Pressure Tubing is under the scrutiny of Ohio's master tubemakers . . . making control tests at frequent intervals . . . testing random samples from each production order far beyond the limits of the usage involved.

For critical pressure piping applications . . . for condensers, heat exchangers, boilers and superheaters — in the range of sizes from ½ to 7½" OD and wall thicknesses from .028 to .375"— mark your prints "*Ohio Custom Made Welded Pressure Tubing.*" There is no equivalent.



Photographs show flare, flattening and crush tests performed continuously on every order. Non-destructive tests include air, water, magnetic, eddy current and visual inspection to insure 100% dependability.

Photomicrograph of polished and acid-etched surface shows perfect microstructure of normalized Ohio Welded Pressure Tubing. Weld area running down the center is now indistinguishable and tube has become, in every sense, weldless.

OHIO

OHIO SEAMLESS TUBE

Division of Copperweld Steel Company

SHELBY • OHIO

Seamless and Electric Resistance Welded Steel Tubing • Fabricating and Forging

Circle 288 on Page 19

Representatives in principal cities. Check leading directories:
THOMAS', MacRAE'S, CONOVER-MAST, SWEET'S, FRASER'S.

A-4800A

Compact cartridge pumps provide pressure lubrication at minimum cost

by E. H. Schanzlin
Chief Engineer, Tuthill Pump Company

An opportunity for savings exists in many original equipment applications involving pressure lubrication . . . where, in many instances, foresight on the part of the designer will permit the use of a "cartridge" pump which can be built directly into the equipment . . . to provide the greatest possible capacity per cubic inch of pump . . . and ordinarily at a price below those for comparable pumps . . . since every possible extraneous element has been eliminated from their design.

14 Different Units

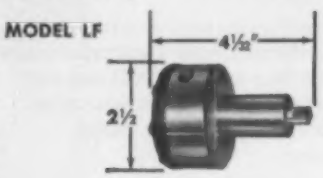
To meet the requirements of these applications Tuthill engineers have developed four different models of cartridge pumps . . . each offered in 3 or 4 sizes for a total of 14 different units . . . for pressures to 200 psi . . . with a capacity range from 56 to 720 gph depending upon pump size and motor speed. These units are all available from stock in any quantity desired. They have been used successfully in many outstanding original equipment applications.

Model LF

Model LF pumps, as shown, have an extremely simple housing and are normally furnished without seals. They are supplied in three sizes with nominal capacities as shown below.

Size	GPH	RPM
00	56	1800
0	105	1800
1	180	1800

(These nominal capacities will also apply to similar sizes of pumps discussed later.)

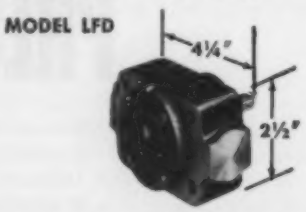


Tuthill manufactures a complete line of positive displacement rotary pumps in capacities from 1/3 to 200 gpm; for pressures to 1500 psi; speeds to 3600 rpm.

Model LF pumps are designed for flange mounting. They offer a choice of internal or external porting. Overall dimensions of these compact units are only 2½" x 4½", and even shorter lengths are possible when pumping conditions permit.

Model LFD

Model LFD cartridge pumps are offered in the same capacity ranges and sizes as model LF. They resemble these basic pumps except that they are provided with a more detailed housing. Model LFD's are designed for flange mounting and normally supplied with either internal porting or ⅜-18 N.P.T. external porting. Shaft seals or ball bearings may also be furnished with these units as an alternate. In the 00, 0, and 1 pump sizes, these units measure 4¼" x 2½" x 3½"

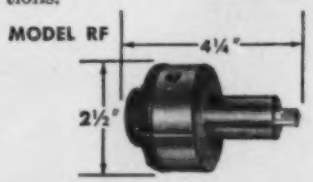


Model LFD pumps are also furnished in pump size 2, with a capacity of 360 gph at 1800 rpm, and 720 gph at 3600 rpm. Overall dimensions are 5⅝" x 3⅛" x 4½".

RF Models

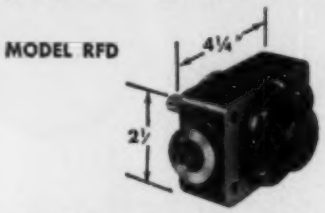
The selection of RF models closely resembles those in the LF range . . . sizes, capacities and general characteristics are identical. However, these units are equipped with Tuthill's special automatic reversing feature which permits driving the pump in either direction without changing the direction of flow . . . with port positions remaining constant . . . without special valving.

The automatic reversing design was developed by Tuthill for applications where the pump must be driven by reversing shafts, or where machinery must be shipped without knowing the ultimate direction of the driving unit. These versatile units have proven their superiority in hundreds of demanding applications.



Model RFD

These units parallel model LFD in capacities, sizes, and general characteristics. Like the model RF above, however, the pumping units have Tuthill's special automatic reversing feature for use with reversing shafts. Dimensions of 00, 0, and 1 sizes are 4¼" x 2¼" x 3²⁹⁄₃₂". Size 2 pumps measure 5⅝" x 3⅛" x 4½".



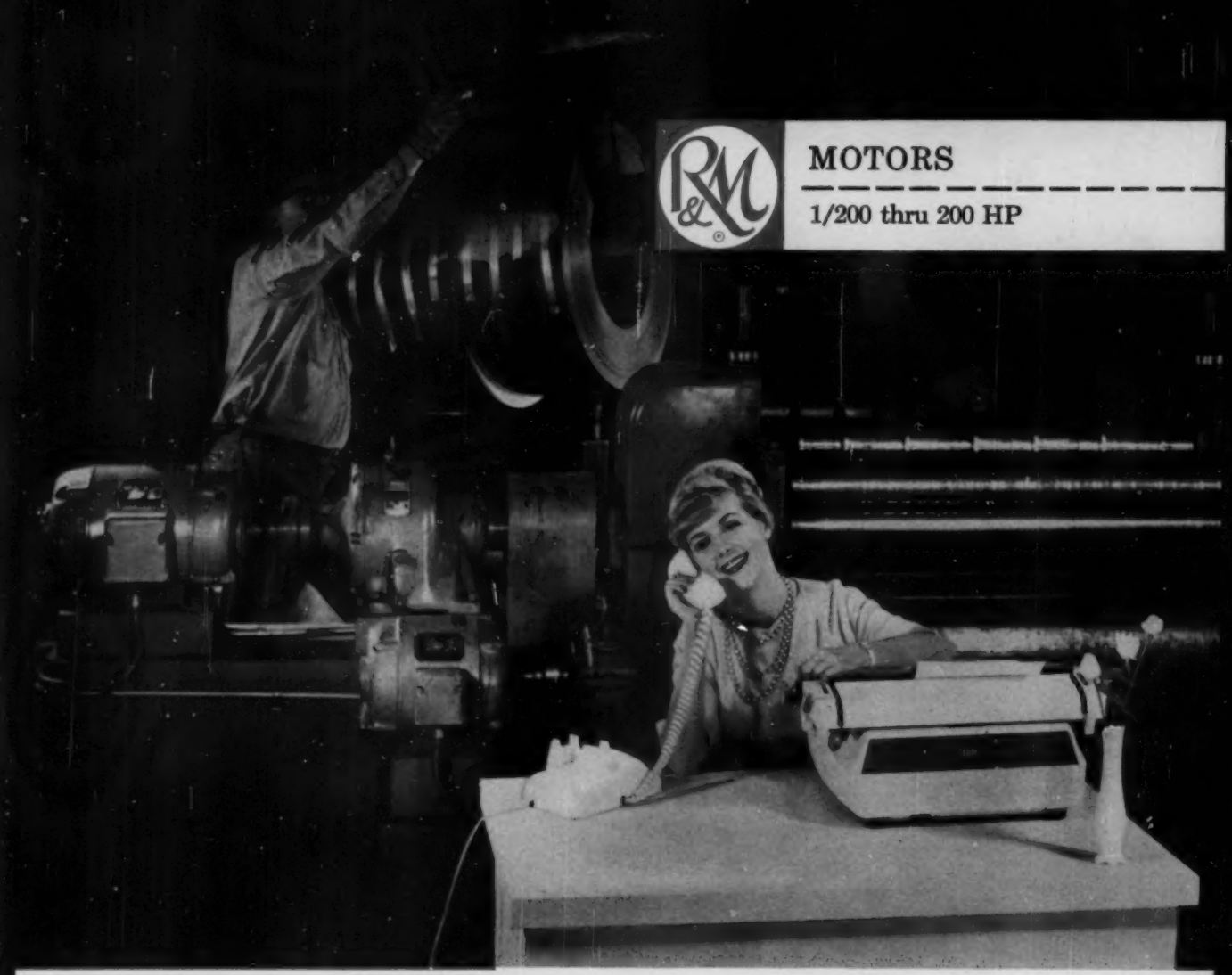
Wide Variety of Alternates

In addition to the basic pump models, various alternates can be provided. For example two alternate shaft modifications are offered for maximum adaptability.

Imaginative use of these cartridge pumps may permit significant savings in your designs. In addition to the economical price, their compactness and light weight can eliminate design headaches. These units offer the maximum amount of lubricating capacity for the minimum amount of pump . . . and often at the minimum expenditure of dollars.

For further details write for catalog section 108. Or, send details on your application so Tuthill can offer suggestions on how these units can be incorporated into your design.

POWER FOR YOUR PURPOSE
TUTHILL PUMP COMPANY
953 East 95th Street, Chicago 19, Illinois



MOTORS

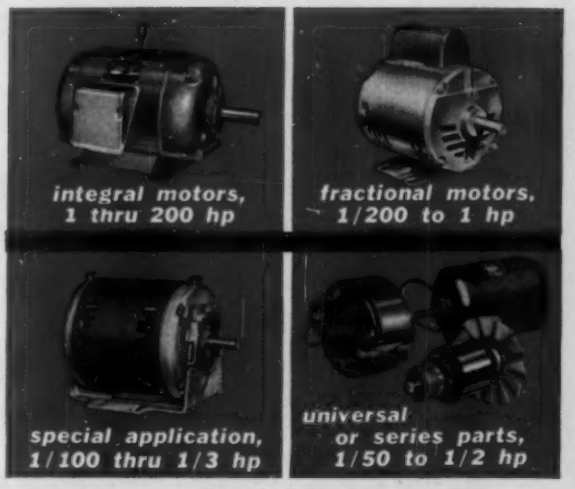
1/200 thru 200 HP

from machine tools to typewriters . . .

. . . Robbins & Myers motors power them all!

Each R&M motor, 1/200 through 200 HP, is electrically and mechanically designed with life-prolonging features which assure dependable operation, simplified installation and low maintenance. From rugged machine tools to complex business machines, there's an R&M motor for every job . . . Fractional and Integral H.P. Motors and Motor Parts in all popular mountings, electrical types and enclosures. Most are ready for off-the-shelf delivery. Others can be quickly produced. Should you require custom motors, R&M's experienced application engineers, aided by modern electronic computers, can furnish the one design best suited to your needs.

Write today for information, or send your powering problem to R&M. No obligation, of course!


integral motors, 1 thru 200 hp
fractional motors, 1/200 to 1 hp
special application, 1/100 thru 1/3 hp
universal or series parts, 1/50 to 1/2 hp

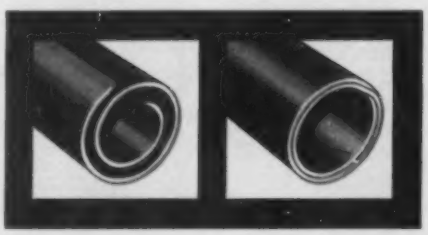
ROBBINS & MYERS, INC., Springfield, Ohio

Fractional and Integral HP Electric Motors • Electric Hoists and Overhead Traveling Cranes • Moyno® Industrial Pumps
Propellair® Industrial Fans • R & M-Hunter Fans and Electric Heat • Trade-Wind Range Hoods and Ventilators
Subsidiary companies at: Memphis, Tenn., Pico Rivera, Calif., Brantford, Ontario.

Circle 290 on Page 19

Bundy can mass-fabricate practically anything

Bundy engineering and design specialists thrive on *your* tubing problems. Backed by years and years of experience, they can often come up with more efficient methods for mass-fabrication of tubing components—incorporating the best design ideas and the best steel tubing ever. With Bundyweld® steel tubing you can make more different complex bends and shapes. And Bundyweld meets Government Specifications MIL-T-3520, Type III; ASTM 254; and SAE specifications. For answers to *any* tubing problem, call, wire, write: Bundy Tubing Company, Detroit 14, Mich.



* * *

Bundyweld, double-walled from a single copper-plated steel strip, is metallurgically bonded through 360° of wall contact. It is lightweight, uniformly smooth and easily fabricated . . . has remarkably high bursting and fatigue strength. Sizes up to ⅝" O.D.

BUNDY® TUBING COMPANY

DETROIT 14, MICH. • WINCHESTER, KY. • HOMETOWN, PA.

WORLD'S LARGEST PRODUCER OF SMALL-DIAMETER TUBING. AFFILIATED PLANTS IN AUSTRALIA, BRAZIL, ENGLAND, FRANCE, GERMANY, ITALY, JAPAN.

WEAR RESISTANT
THOMSON

60 Case

AVOID the HIGH COST and difficulty of fabricating long, hard & straight parts by conventional methods!

hardened and ground

SHAFTS, ROLLS, GUIDE RODS and other long-round parts

ELIMINATE WEAR and REDUCE COST

60 Case is the result of over 15 years of experimental work and production experience with hardened and ground shafts which are a requirement for BALL BUSHINGS, the Linear Ball Bearing manufactured by Thomson Industries, Inc.

The special techniques and equipment that have been developed enable high production rates and low handling costs. This permits big savings over conventional methods which are plagued with erratic warpage, straightening and resultant grinding problems. Finished *60 Case* parts frequently cost less than the scrap losses that result from conventional methods.

60 Case material has a surface hardness close to 60 on the Rockwell C scale which is essential to resist wear.

Long lengths of material ranging in diameter from ¼" to 4" are stocked to enable prompt shipment of *60 Case* parts, with or without special machining. *Write for literature and name of your local representative.*

For emergency needs call collect
MAnhasset 7-1800

ADVANTAGES of *60 Case*

- COST REDUCTION
- HARD BEARING SURFACE
- NICK-& DENT-PROOF
- ACCURATE DIAMETERS
- GROUND FINISH
- STRAIGHT PARTS
- DELIVERY FROM STOCK
- ADDED STRENGTH
- UNIFORM HIGH QUALITY

TYPICAL *60 Case* PARTS

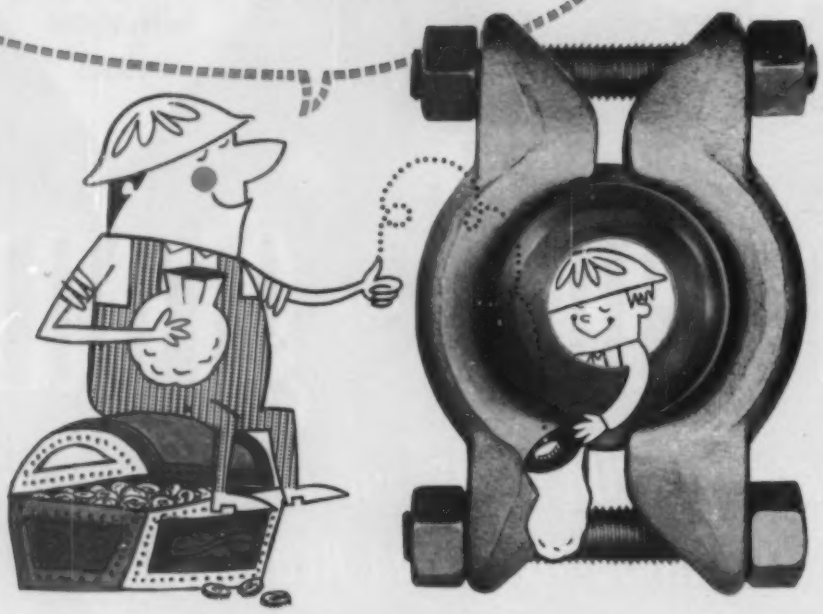
GUIDE RODS • SHAFTING • ROLLS • TRAVERSE RAILS
PISTON RODS • ARBORS • LEADER PINS • TIE RODS
KING PINS • AXLES • CONTROL RODS • GUIDE POSTS
MANDRELS • BEARING ROLLERS • SPINDLES

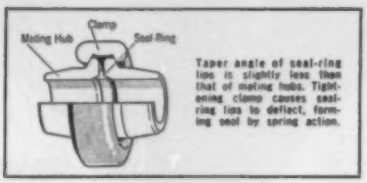
THOMSON INDUSTRIES Inc.
Dept. C-5, Manhasset, New York

Circle 292 on Page 19

PARTS HARDENED to 60 C...
increase life... reduce cost!

How Grayloc® Pipe Connections Can Save You Money




Mating Hub
Clamp
Seal Ring
Taper angle of seal-ring lips is slightly less than that of mating hubs. Tightening clamp causes sealing lips to deflect, forming seal by spring action.

Money isn't always measured in dollars — around a shop or plant it may be disguised as space, time, effort, weight, trouble and inventory. With GRAYLOC Pipe Connections, you're saving in all these categories.

Specifically, GRAYLOC Connections are smaller than equally rated flanges so they weigh less. With only two bolts per connection, they take less time, trouble and effort to assemble.

The completely re-usable, all metal seal ring eliminates the need for replacement gaskets, so you save again on inventory and on maintenance time. Fluctuating temperatures and pressures, external stress or vibration never lead to loose, leaky GRAYLOC Connections. After they're assembled, they never need re-tightening.

GRAYLOC Connections are manufactured in standard stock sizes from 1″ to 30″, with special sizes available on request. They can easily be made of corrosion resistant metals on short notice. To learn the complete, validated GRAYLOC story, write today for the GRAYLOC catalog.

GRAYLOC SALES DIVISION

GRAY Tool Company

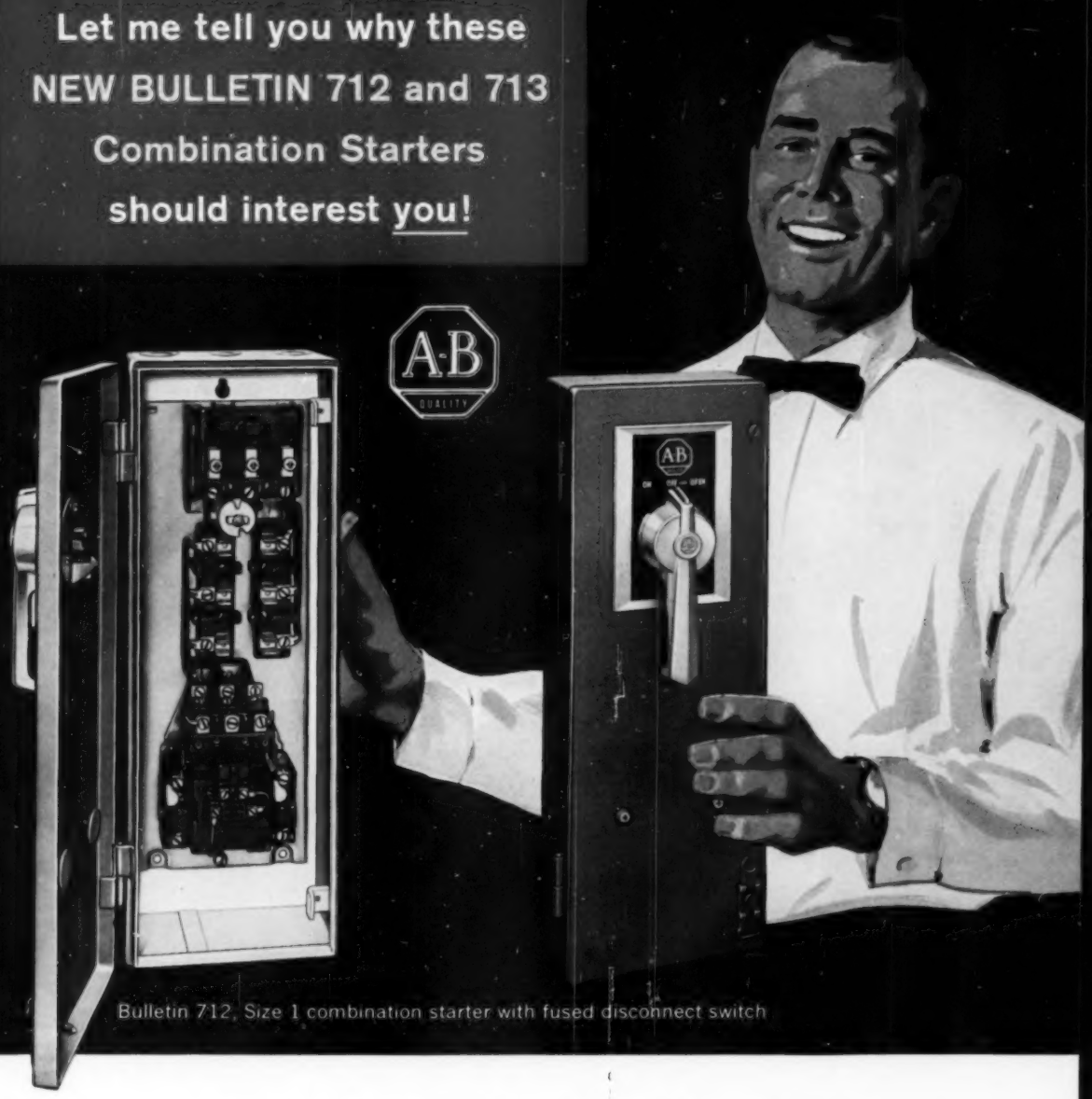
P. O. BOX 2291 • HOUSTON 1, TEXAS • Riverside 7-1240

6113

Circle 293 on Page 19

Circle 294 on Page 19→

Let me tell you why these NEW BULLETIN 712 and 713 Combination Starters should interest you!



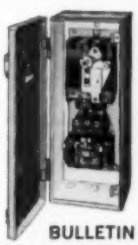
Bulletin 712, Size 1 combination starter with fused disconnect switch

They have — Smaller Size...Greater Switching Capacity... Greater Reliability...Longer Life...Complete Safety... Generous Wiring Room...Simple Design...Businesslike Beauty

Rating for rating, the new Bulletin 712 motor starter will outperform and outlast all others. Complete safety for the operator is assured because the cabinet door cannot be opened until the lever is moved to the OPEN position, which opens the visible contact disconnect switch.

The Bulletin 713 combination starter provides similar features for complete safety, but uses an ITE circuit breaker as a method of disconnecting.

Brooks Stevens, famous industrial designer, has given the entire line of enclosures, an undeniable "eye appeal"—an asset to any modern machine tool or industrial installation. Please write for details, in Publication 6100: Allen-Bradley Co., 1316 S. Second Street, Milwaukee 4, Wis.



BULLETIN 713
Combination Starter with Circuit Breaker in Nema Type 1 Enclosure.

19-61-RM

ALLEN-BRADLEY

Member of NEMA

QUALITY MOTOR CONTROL

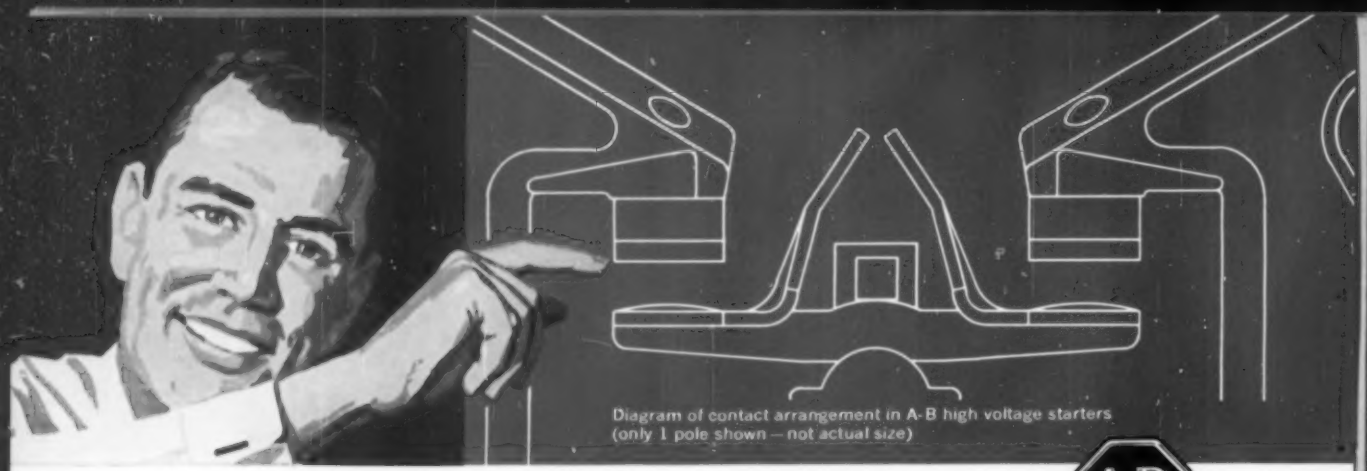


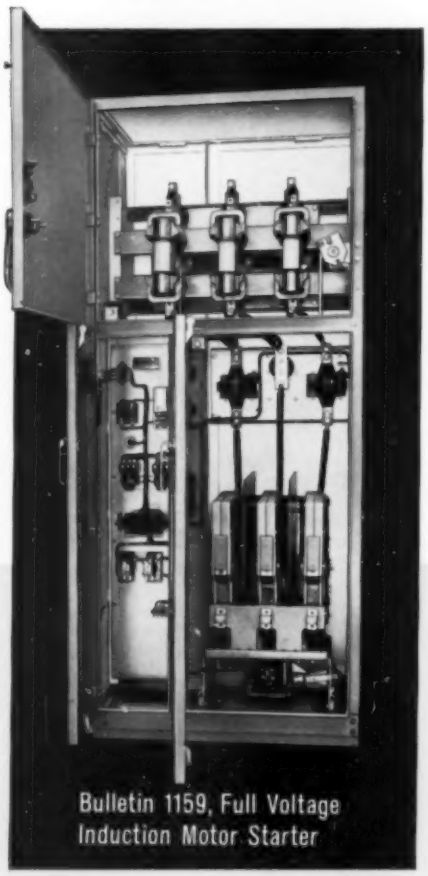
Diagram of contact arrangement in A-B high voltage starters
(only 1 pole shown — not actual size)

Would You Believe That

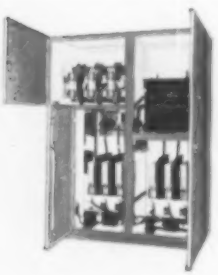
3/8 OF AN INCH IS THE REASON

for the Reliability and Long Trouble Free Life of A-B Starters Rated at 1500 hp, 2300 v; 2500 hp, 4600 v!

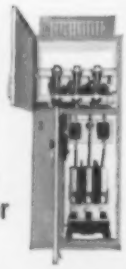
Allen-Bradley high voltage starters were designed and are built to provide millions of trouble free operations. An astounding claim—for this class of apparatus—but *true!* The extraordinary performance of the air break contacts is the result of extremely short contact travel—only 3/8 "! Naturally, such short travel reduces pounding and contact wear to a minimum. Also, the famous Allen-Bradley solenoid principle of operation is so simple that nothing can go wrong. Maintenance-free, double break silver alloy contacts are used throughout. Allen-Bradley high voltage starters are available for all types of motors and all types of service. For full details please write today for Bulletin 6080 to: Allen-Bradley Co., 1316 South Second Street, Milwaukee 4, Wisconsin.



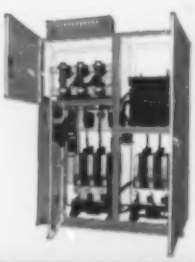
Bulletin 1159, Full Voltage
Induction Motor Starter



Bulletin 1172, Reduced Voltage
Induction Motor Starter



Bulletin 966, Full Voltage
Synchronous Motor Starter



Bulletin 983, Reduced Voltage
Synchronous Motor Starter

19-61-RM

ALLEN-BRADLEY

QUALITY
MOTOR CONTROL

DESIGN
December 7, 1961

What Do You Do?

YOU'RE an engineer. What do you do, exactly?" You must have heard this question before, and maybe you don't take it too seriously. But what if the inquirer is the parent of a promising youngster who has demonstrated mechanical aptitudes or has been told that he has engineering abilities? The answer could be important.

The general public doesn't see engineers at work—as they see plumbers, store clerks, and bus drivers, or even clergymen, lawyers, and doctors. Of course, out on the highway people see men in field boots squinting through transits—"civil engineers, of course." They know that their airliner carries a flight engineer, glimpsed behind an imposing array of instruments and controls. Then there is the popular image of the design engineer, shackled to his drafting board and T-square. That unfortunate image dies hard, even among engineering students, and sometimes persists after graduation.

On the other hand, the achievements of engineers are often credited to scientists. In reporting on "Saturn's Success" *Time* magazine twice mentioned "the scientists" as if they were the key people responsible—with nary a mention of the engineers. And a news release the other day attempted to impress us by saying that the designers of a certain new product are "more than just engineers—they are scientists."

Small wonder that the general public fails to connect engineers with the great creative accomplishments of our day, and instead associates them with the routine tasks of technicians.

Engineers can help greatly to clarify popular notions about the research, development, and design engineering team. A pair of simple definitions, recently approved by ECPD, point up the distinction between engineers and scientists:

"Engineers are primarily creators of things and services useful to man; scientists are primarily discoverers and interpreters of information about nature."

The place of the technician can be clarified if he is identified as an essential aide to both scientists and engineers in carrying out tasks that may or may not require some creativity but do not require the advanced educational standards of either scientists or engineers.

How would you explain your function as an engineer in terms that a layman could understand? Isn't it about time we did a little bragging?

Colin Carmichael

EDITOR

Engineering for

Product Innovation

An inside look at the factors which influence productivity

Functional Organization

Personnel Distribution

Risk Capital

Professional Climate

Job Descriptions

Development Authorization

Engineering Management

W. H. YEAMANS
Manager—Engineering
Electronic Specialty Capacitor Product Section
General Electric Co.
Irmo, South Carolina

Circle 25-2 on Page 19 for extra copy.

HAS the demand for your line of product shown a decline during the past year or two? You may not really have looked at your product to see if, perhaps, it could be the underlying cause of low sales volume. Your customer looks it over closely. He sees other companies making a similar product, often at a lower price.

It is not happenstance that resourcefulness and innovation wane as a business grows. In effect, competition sees the advantage of making a competitive line and, in doing so, capitalizes on the knowledge gained through use of similar products in the field.

One answer is product innovation. This does not mean merely changing the color of the device or just adding peripheral equipment. It does mean formulating a new idea to do the same job better or at a lower cost to the customer.

An engineering organization must have inventive balance encompassing such factors as business climate, optimum managerial direction, decision-making ability, and functional responsibilities for both the individual and supervisor. Otherwise it will not get results.

Functional Organization: In some industries a project is assigned to a group where lines of authority are not clearly defined. These people often have only a vague idea what is required of them. And, when they do come up with a new concept that looks good, the project often lies dormant because the product group does not have the time or resources to carry it through. The expression "I am too busy" or "that is not my responsibility" is often the result of such planning. A typical line chart shows where some of these conditions might exist, Fig. 1.

Here, many supervisors and other personnel are working on separate small phases of engineering. Each group must go through several steps to know the real program. An individual has difficulty getting an answer. There are too many chiefs and no indians. Also absent is effective line authority which is so important for decision-making and pinpointing responsibility.

Personnel Distribution: Frequently management is not geared to the level of education and experience of its engineering talent. The ratio of Ph.D. to M.S. and bachelor degree graduates should be balanced. However, ratios will vary according to product or service.

Risk Capital: Unless the prospect of success in developing and designing a new product is better than 98 per cent, many companies are unwilling to spend the money. It is in such situations that management often decides that another design change to the good old reliable line is the correct approach. Maybe so, but the greater the risk, the larger return when successful.

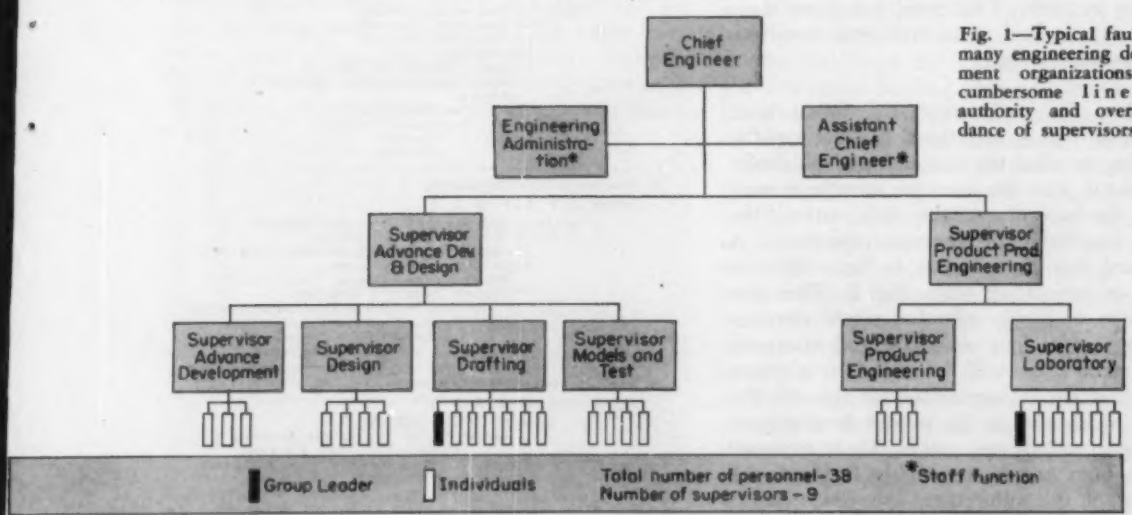


Fig. 1—Typical faults of many engineering department organizations are cumbersome lines of authority and overabundance of supervisors.

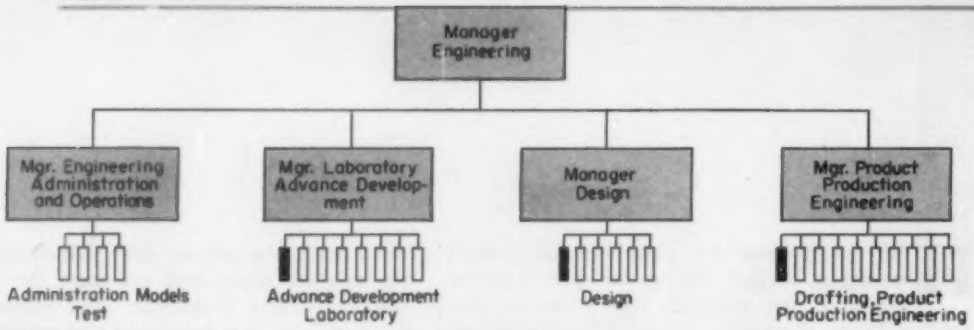


Fig. 2—Streamlined organization provides more direct lines of authority with reduced number of supervisors.

Total number of personnel-33
Number of supervisors-5

Professional Climate: "Climate," one of the more important considerations today, is overlooked by many but will pay dividends. Many organizations lack the attributes leading to a proper climate for professional people. Unless engineers are treated as professionals, success takes longer to achieve.

Such items as position guides, which define the responsibility of the individual, are nonexistent in many engineering groups. This being so, how to effectively measure whether the individual is doing a satisfactory job presents a problem. The design engineer often has not visited a customer because policy dictates that only the sales engineer should spend time going over the needs of a particular account. The engineer cannot be expected to do his best when he lacks the full understanding of the problem.

Is the engineer offered the opportunity to increase his education and thus become worth more to the company and himself? This may be difficult in some localities, but where educational facilities are available, is full advantage taken of them? The trend in some industries has been to create barriers by failing to organize and provide the right climate for expanding business. This trend has many dangers which can only lead to an inefficient, noninnovating engineering function.

Organization: An engineering department must be so organized that it can think and act rapidly, always keeping in mind the customer and his needs. Decisions coming from the manager sometimes must be made on the basis of available facts, without the comfortable knowledge of personal experience. A straightforward line organization is better able to function as an innovating team, Fig. 2. This type of organization is highly effective where development projects are of long duration, and extremely complex. Functions are well defined. The manager of each subfunction is responsible for the effective performance of his part in the overall development. He has to report to only one person. He is measured by only one man and is thoroughly familiar with the objectives of this subsection. The organization pictured in Fig. 2 is simpler, and more direct than Fig. 1. It permits the organization to function more smoothly, and with five less people. A realigned organization that differs from Fig. 1 and 2 appears in Fig. 3. The setup combines line authority with product responsibility, and is most effective where a larger number of smaller innovations must flow continuously.

A group of this type can take an idea and in a relatively short time produce models and test results to get the needed answers. More product knowledge is concentrated in specific areas for speedier results which require less of the "re-inventing the wheel" approach. Here, even with various types of proven technical feasibilities, problems can be slanted to special product groups for engineering results. Only thirty-three persons are required, as in Fig. 2. Total output will be considerably more

Table 1—Program for Professional Personnel

1. Applied Research and Advance Product Engineering
Levels 7 6 5 4 3 2 1

- Senior Development Engineer
- Senior Analytical Engineer
- Senior Statistical Engineer
- Metallurgist
- Advance Development Chemist
- Materials Development Engineer
- Analyst
- Development Chemist
- Development Physicist
- Chemist
- Physicist

2. Product Design Engineering
Levels 7 6 5 4 3 2 1

- Advance Materials and Processes Engineer
- Senior Engineer-Dry Capacitors
- Advance Design and Production Engineer
- Senior Reliability Engineer
- Senior Design Engineer
- Product Reliability Engineer
- Product Design and Production Engineer
- Design Engineer
- Specialist-Design and Production Engineering

3. Product Production Engineering
Levels 7 6 5 4 3 2 1

- Advance Project Engineer
- Senior Product Production Engineer
- Product Production Engineer
- Specialist-Production Engineering

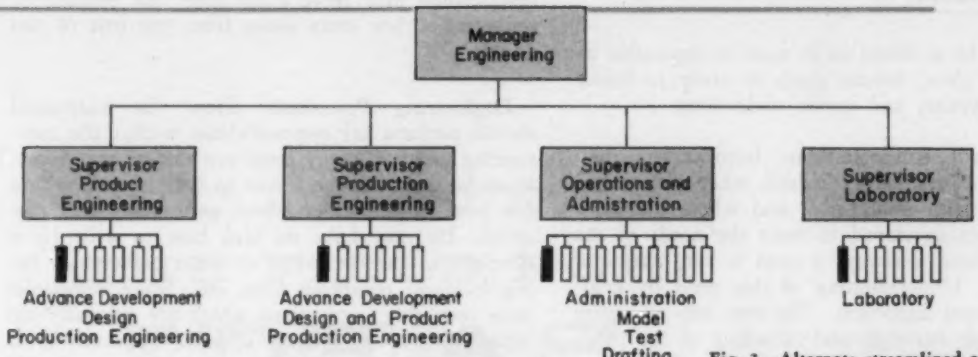


Fig. 3—Alternate streamlined organization is most effective where a large number of small projects must flow continuously.

than that provided by the organization in Fig. 1. Also, fewer supervisors and managers are needed.

Personnel Requirements: The number of professional people with Ph.D., M.S. and bachelor degrees as related to nontechnical personnel is important. A product engineering organization heavy with Ph.D.'s, for example, will not function as well as a balanced group with other degrees of education and training. This is primarily because scientists are interested in basic phenomena rather than the engineering details of a product. When the theory has been proven technically feasible, the project may be dropped, mainly because no product engineering group has been keyed into the overall project, or because the ratio of engineers to scientists is too small. This is not only discouraging to the Ph.D., but affects the general engineering climate and output of the section.

It is necessary that proven ideas generated by the laboratory and advance development personnel be picked up by the design and production engineering group for check-out and analysis as a product or part. If only one in five ideas can be used, this is generally worthwhile. Although with various kinds of business, the relationship between Ph.D.'s, M.S., graduate, and supporting personnel will vary, a rule of thumb which has proven effective is:

Personnel	Per cent
Ph.D.	7
M.S.	11
B.S.	30
Technical	32
Others	20

How this breakdown is separated by function is shown in Fig. 4.

Job Descriptions: One of the most important parts of engineering control is knowing each position requirement as part of the whole effort. Many times a capable engineer is hired without being told what is expected of him. When the individual does not receive a guide, it takes him three times as long to find his niche in the organization.

The position guide should be written to coincide with, but not overlap, other positions within the organization. They should be designed to allow for growth of the engineer. They must spell out the responsibilities and not be written to fit the individual. A properly thought through guide can increase an engineer's productivity. It not only directs his effort, but allows for appraisal of this performance over a given period of time. If the engineer knows that there are growth possibilities for him, the chances of keeping him, and getting more from his planned actions, are more assured. An example of such a growth program is shown in Table 1.

Although three major engineering functions are shown, this would vary by organization. Each function is subdivided into seven levels. For example, a man may start at level 2 as Design Engineer. He can move up in the design category or be moved into either of the other two functions. His movement depends a great deal upon his self development and other factors, most of which he creates himself.

Once a man knows what is expected of him through a written guide, and associated appraisal methods, he becomes a better engineer. For each responsibility there must be a basis for appraisal, Table 2. Note the short specific responsibilities and means of appraisal. Under no conditions should the

Table 2—Job Description and Appraisal Sheet

Position Title: Design Engineer

I. Principal Responsibilities and Basis for Appraisal (In addition to observation and judgment)

Responsibility	Basis for Appraisal
A. Operating	
1. Provides new or modified product designs to obtain greater share of existing market.	Industry position.
2. Establishes and adheres to design schedule.	Design schedule.

requirement be so broad as to make it impossible to measure. A clear, concise guide is easier to write, easier to appraise, and better understood.

Development Authorizations: Innovations come from technical, trained individuals where the proper climate has been established, and where organization has been developed to meet the needs of the business. There is always a need to stay ahead of competition. Understanding of this need by engineering is most important. The best way to assure complete and thorough understanding of the problem is to write up a development authorization. This authorization pinpoints the need, establishes schedules and costs, and covers virtually all functions of the business. It makes functional managers fully aware of the problems, needs, and results to be obtained, because they too sign the authorization. The per cent risk to successfully complete the project must be a part of the authorization. Once the authorization has been approved, work is started. Regardless of whether this development is strictly a design project or basic development, new concepts

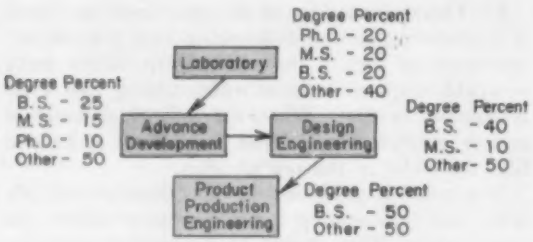


Fig. 4—Personnel distribution varies according to department function.

that come from the work must be proved. It is here that good thoughts are often dropped, because no one has time to check them out. They lie just outside the bounds of the authorization.

Product Cost: Nothing delays a project more than attempting to design a product as cheaply as possible. When a new product is first placed on the market, generally there will be a demand for it. When a competitive product is introduced, costs must be reduced. By this approach, two basic results are attained: 1. A design that works right from the start, and 2. Improved quality through design innovations as a result of production and field experience.

When innovations are sought, low cost should not be the number one goal. Plan first to prove that the unit will meet the specifications; look at costs as the next consideration. After test and evaluation, the required manhours of development and design time may more than offset the benefits of removing a few cents more from the cost of the design.

Engineering Procedures: How the individual should perform his responsibilities within the engineering group is many times not understood. Sometimes he must ask the fellow in back of him to find out how he should go about getting his idea patented. He may have no idea how to write up a development authorization or what policies are being followed regarding trips, etc. Some companies issue operating instructions which are generally too broad in scope. A more effective approach is to have specific engineering procedures directed to aid the engineer in his daily work. These procedures must be kept up to date if they are to be of value. Knowing the goals is another tool to create the proper innovating climate.

Engineering groups which realize the fullness of their responsibility and relationships are more acutely aware of progress by teamwork. This effect, created by climate and organization responsibilities, has the effect of accelerating competitive spirit. Engineers are anxious to take over items of interest from the laboratory just as fast as they can. No good item has to be sold.

The engineer is product oriented. He wants to make his design better than the other fellow's and once he sees a possible technical breakthrough, he's anxious to pick up the proven concept and incorporate it into his product as a modification or as a new device. This is true of several areas in our own operation at GE. A new foil treatment, for example, produces better electrical qualities which makes it advantageous for use in design application. A new cleaning method which has shown extremely low leakage characteristics is another item, and there are many others.

Management: Engineering management is the real key to overall success. The manager today has to deal with engineers and scientists with many varied technical disciplines and experiences. The manager who is also a professional must deal with his engineers as a professional, and on an individual basis. Along with this, he must encourage them to keep up to date in their fields by being active in professional organizations.

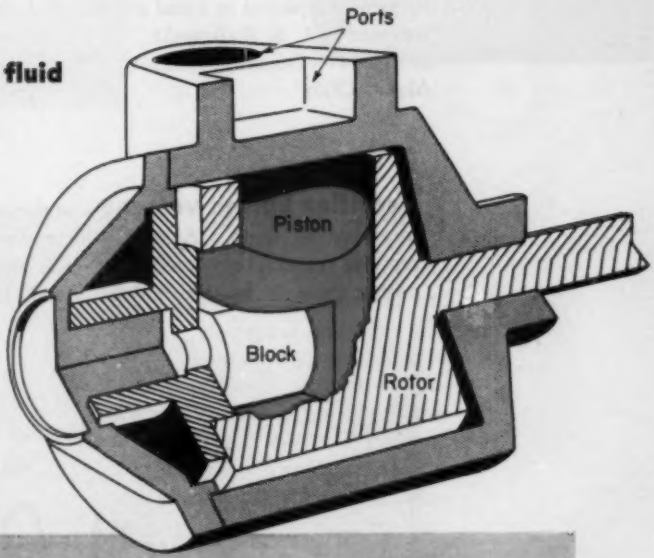
Just as important, he must resolve any doubt about the relationships of individual contributors as well as supervisors so far as pay, hours of work, and other conditions are concerned. The real challenge to the manager is to effectively integrate the innovations through the engineering disciplines to meet the overall engineering objectives.

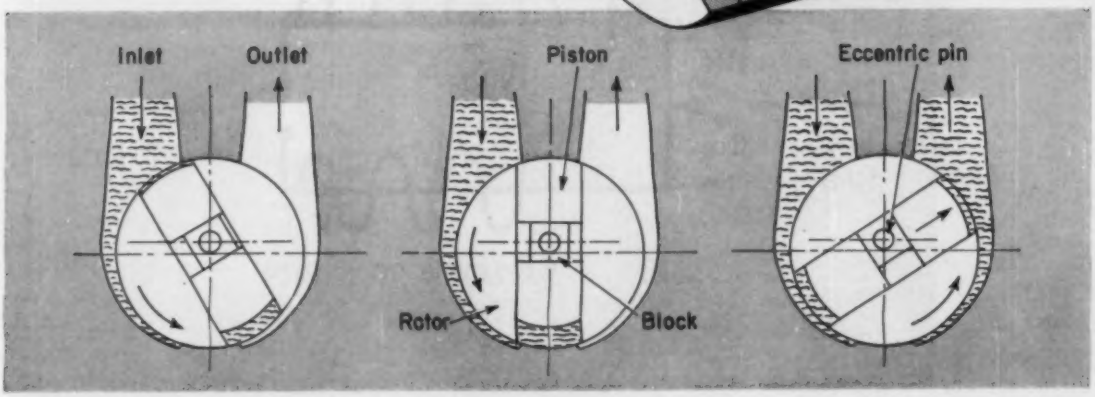
Because corporations need product innovation to maintain business security, it is essential that engineering organize to assure new products for the future.

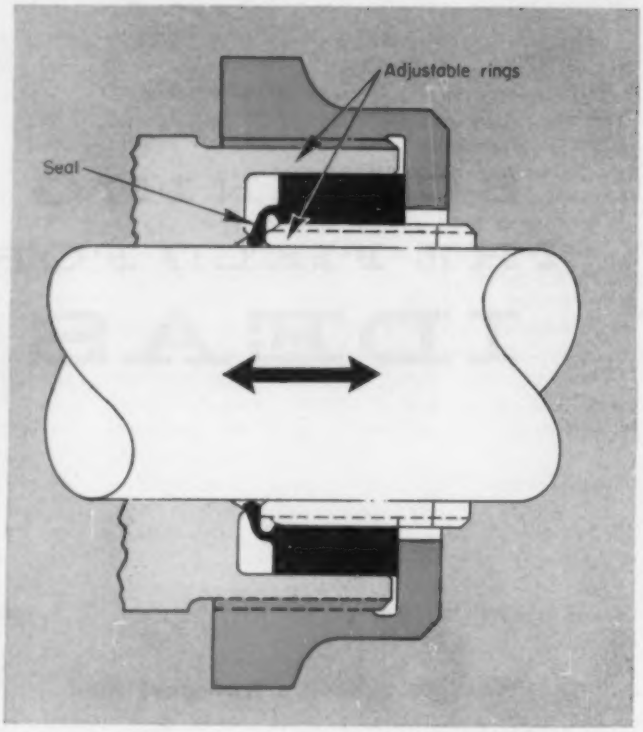
The engineer and scientist are trained for this task, and when they are subjected to the proper climate, well organized and managed, then innovations will result.

SCANNING THE FIELD FOR IDEAS

Whirling cylinders transport fluid from suction to pressure side of a hydraulic pump. The piston is located on an eccentric pin so that each revolution of the rotor causes the piston to reciprocate in its cylinder and produce a complete cycle of suction and discharge. Principle employed in a pump by Parkinson Cowan Co., London, England.

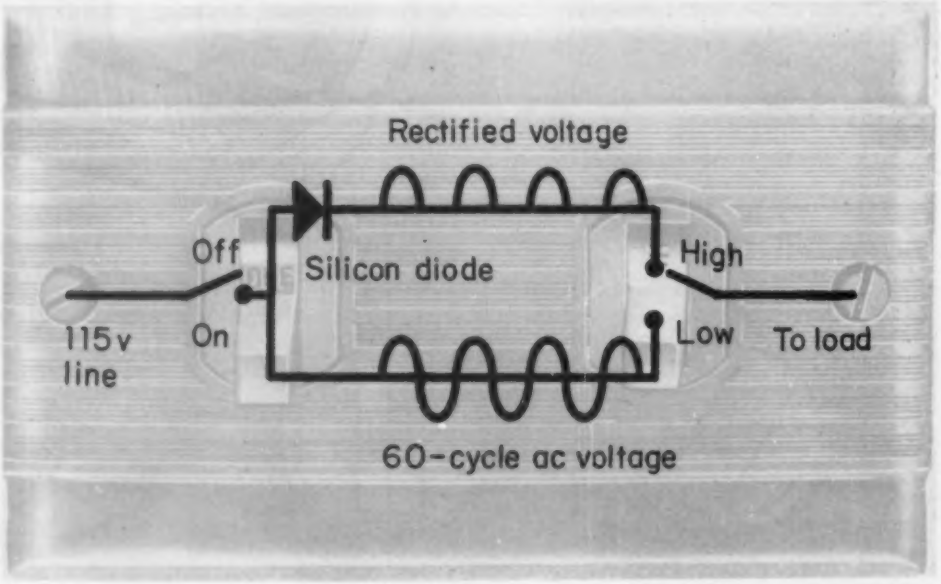


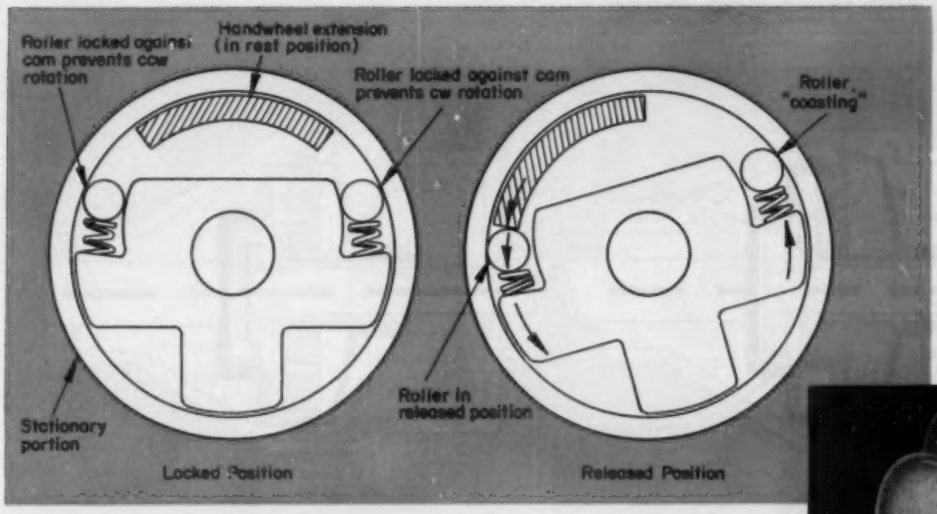


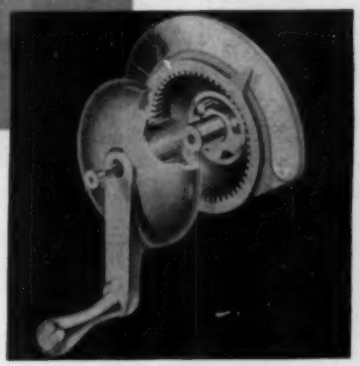


Adjustable metal lip seal with narrow sealing face provides high unit pressure for sealing but keeps break-out force low. To provide for adjustment of the seal edge unit load, adjustable rings move the sealing surface axially in relation to the main portion of the seal. Principle employed in a seal reported by L. S. Bialkowski of B. F. Goodrich Co., Akron, Ohio.

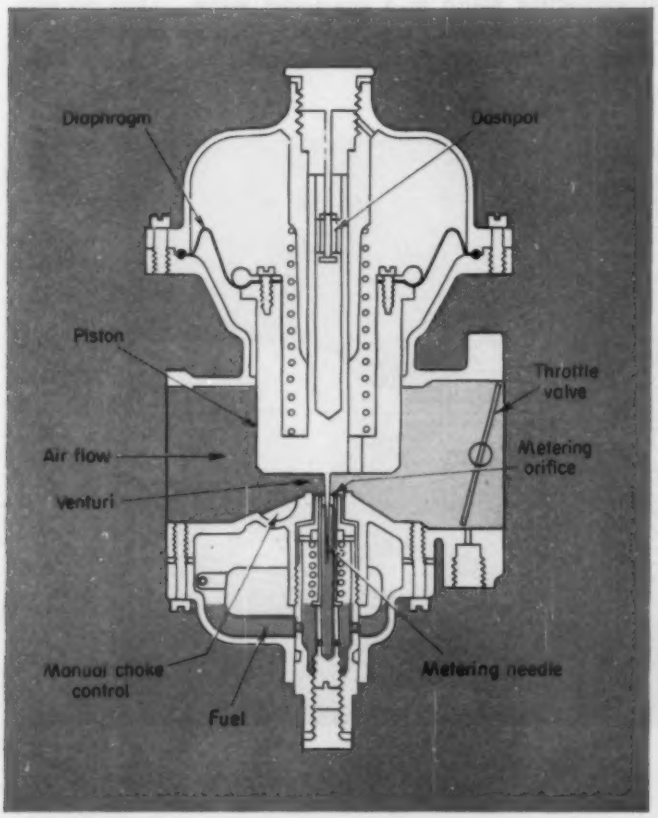
Rectifier halves voltage to dim an incandescent lamp. A small silicon-diode rectifier permits only one-half of each alternating cycle to be transmitted. Small size of diode and lack of heat generation permit the unit to be mounted in a standard wall-outlet switch box. Principle used in a control by Bryant Electric Co., Bridgeport, Conn.



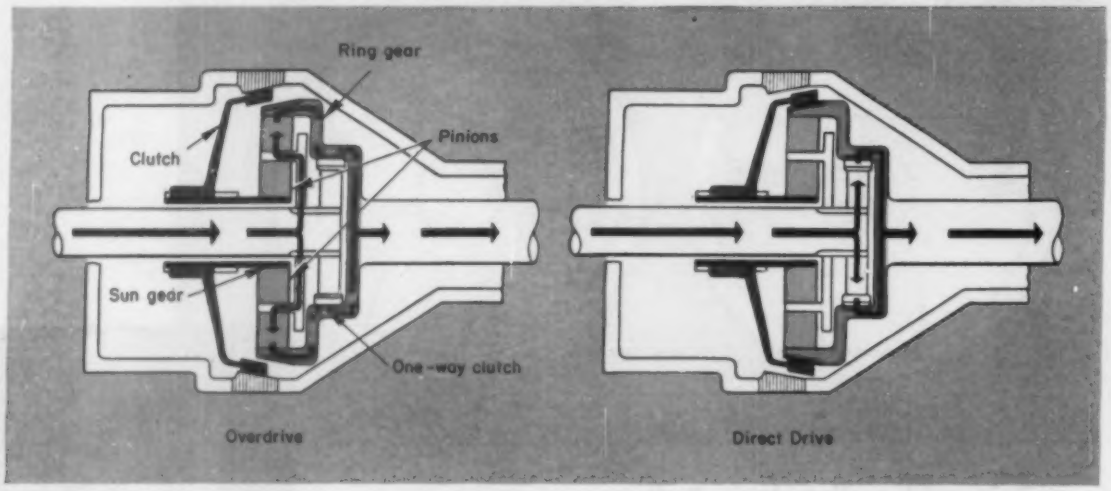




Releasable rollers lock shaft of a speed-changing device to prevent rotation by feedback forces. However, when input handle is moved in either direction, the corresponding locking roller is released. Principle employed in a self-locking speed control by U. S. Electrical Motors Inc., Los Angeles, Calif.

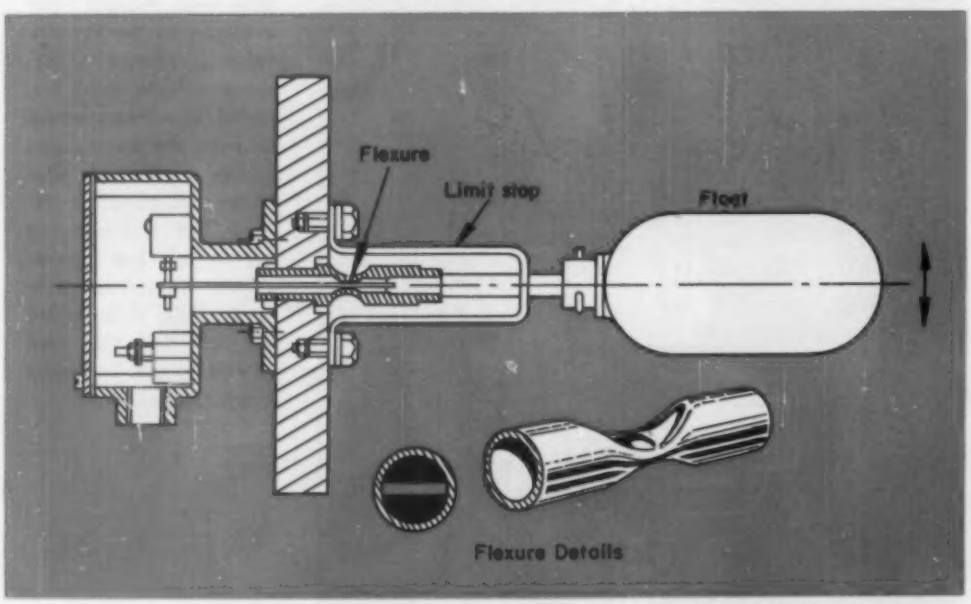


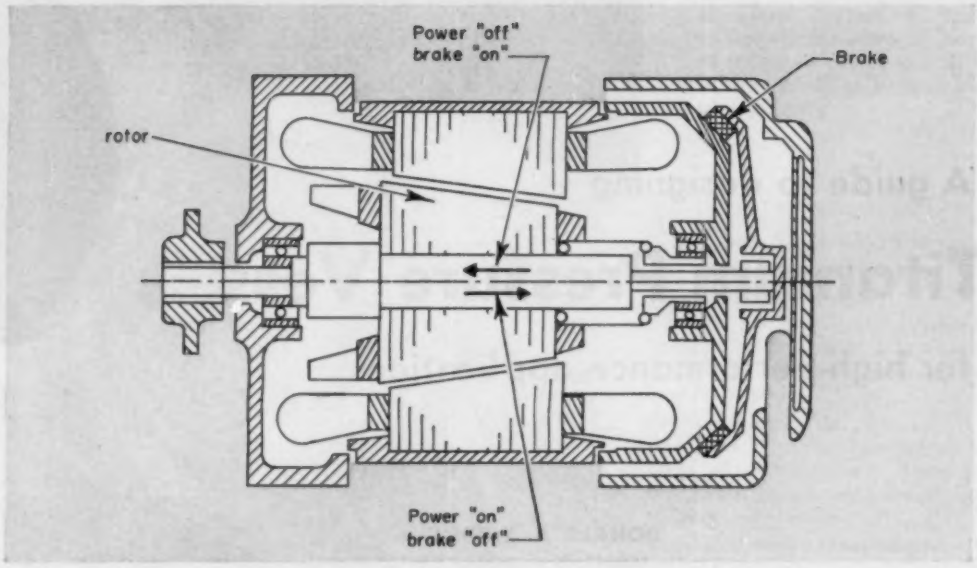
Variable venturi controls both air and fuel flow to adjust mixture ratio in response to engine-speed changes. For example, as the throttle valve is opened to increase vehicle speed, the added manifold vacuum between the throttle and piston causes the diaphragm to raise the piston. The fuel-metering needle is thus repositioned to accommodate the fuel flow to the added air flow. Principle used in a carburetor by Bendix Corp., Elmira, N. Y.



Nonfreewheeling overdrive, whether in "direct" or "overdrive" operation is provided by clutch connecting the ring gear and sun gear of a planetary gear set. Although normal direct drive is through a one-way clutch, the ring-to-sun clutch permits engine braking and reverse operation. Principle employed in an overdrive unit by Auto Transmissions Ltd., Coventry, England.

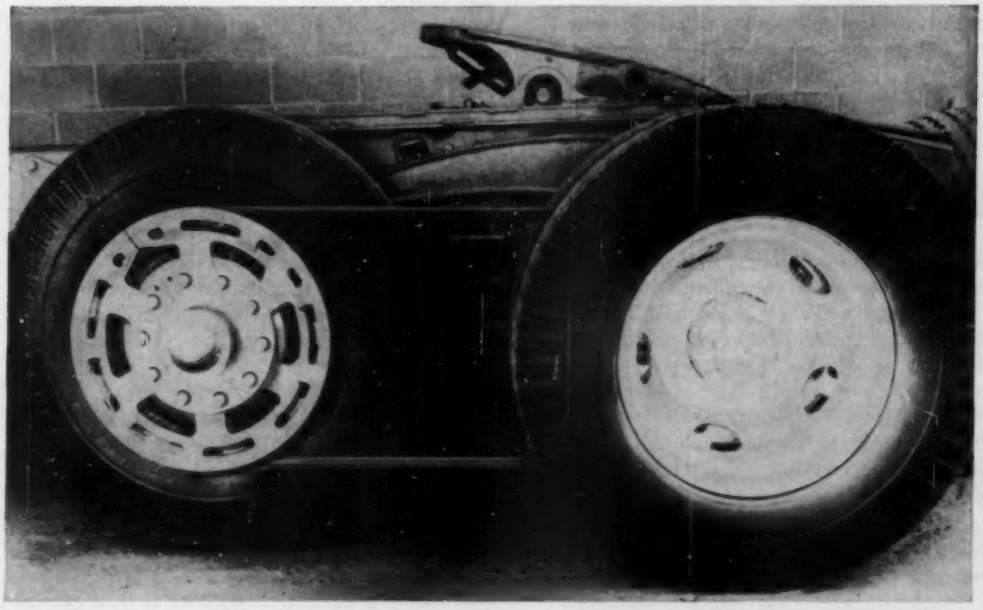
Flexure seal transmits motion to permit a float to operate a precision snap-action switch in a liquid-level alarm. Thus, no additional pivots or sealing means are required. Principle employed in an alarm switch by Associated Electrical Industries Ltd., Harlow, Essex, England.

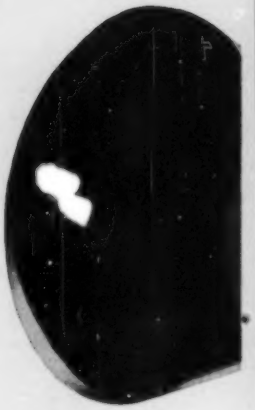




Tapered motor rotor moves axially to operate a built-in brake. When the motor is "on," its brake is released. When the motor is turned "off," the spring-loaded brake provides quick stops. Principle employed in a power unit by Brown, Boverie and Cie, Baden, Switzerland.

Belts drive wheels of "dead" axle on a tandem-axle truck. The V-belts run on split-rim sheaves mounted on each inside wheel. This drive arrangement increases traction and reduces the wheel hop and road shock normally produced when the wheels bounce over uneven road surfaces. Principle employed in a drive system by Gates Rubber Co., Denver, Colo.





A guide to designing

Titanium Pressure Vessels

for high-performance applications

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THE combination of high strength and low density makes titanium one of the most efficient of available engineering materials. Consequently, titanium vessels serve as fuel containers, actuators, and attitude-control devices in missiles and space probes, and as air and brake-fluid reservoirs in manned aircraft. This state-of-the-art report surveys today's titanium pressure-vessel picture: The currently used alloys, design considerations, fabricability of materials, and the cost trend.

Alloys

The four titanium-alloy grades that best lend themselves to pressure-vessel construction are: Ti-6Al-4V, Ti-5Al-2.5Sn, Ti-13V-11Cr-3Al, and Ti-7Al-4Mo. A fifth grade, Ti-6Al-6V-2Sn, is now being evaluated for this application. Density of Ti-13V-11Cr-3Al is 0.17 lb per cu in.; that of the other grades, 0.16 lb per cu in. (Density of steel is 0.28 lb per cu in.) These materials are produced by the double vacuum-melting process to insure high purity and low gas content.

Ti-6Al-4V: This alloy has been specified for most titanium pressure vessels built to date because of weldability, toughness, and good strength and ductility characteristics over a wide range of temperatures. Due to its wide use, the largest amount of design, production, and service data is available on this alloy.

Vessels of Ti-6Al-4V alloy have been used in both the annealed and heat-treated conditions, at cryogenic and at ambient temperatures. In general, more heat-treated vessels are in service. Available forms include bar, sheet, plate, and extruded shapes. Properties of bar stock and forged sections are shown in Tables 1 and 2.

A typical heat-treating cycle for Ti-6Al-4V is: 1. Solution treat at 1550 to 1750 F, 30 to 60 min. 2. Water quench. 3. Age at 900 to 1000 F, 4 to 8 hr. 4. Air cool. Time and temperature specifications within these ranges depend on section size and desired strength-to-ductility relationships.

Ti-5Al-2.5Sn: This alloy grade has exceptional notch toughness at temperatures in the range of liquid hydrogen, Table 3. Under cryogenic conditions, low interstitial content is desirable, with critical control on oxygen levels (since nitrogen content in most titanium grades is already controlled to about 0.03 per cent by weight).

Evaluation of Ti-5Al-2.5Sn ingots, produced with oxygen contents ranging from 0.09 to 0.24 per cent

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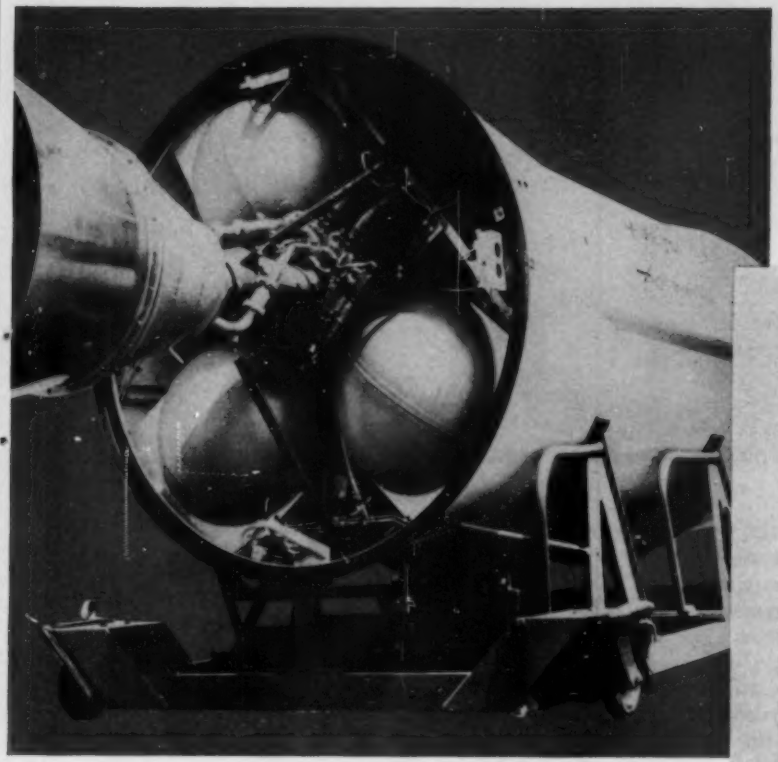


Three titanium spheres in the pressure-feed system of the Ablestar rocket engine save 60 lb of weight—at a cost of $23.85 per lb (compared to steel vessels). Vessels store helium at 4350 psig.

by weight indicates that an oxygen level of about 0.12 per cent provides the best combination of room-temperature tensile properties and cryogenic notched strength, Fig. 1.

Ti-13V-11Cr-3Al: The beta alloy, sometimes called 120 VCA, is heat-treatable to extremely high strengths—yields of 170,000 psi and tensiles of 190,000 psi—with elongations averaging about 5 per cent. The largest titanium forgings ever produced—36-in. diam solid rocket motor closures—were manufactured from this grade.

For pressure-vessel applications, the beta grade is expected to see extensive service where high strength is required at temperatures ranging from −100 to +600 F. At present, annealed beta is used for air-reservoir bottles in the B-58 escape capsules, with the option available for heat-treating should further weight reduction be required.

The beta alloy lends itself to strip-rolling techniques, is weldable and formable in the annealed condition, and will be readily available if demands for thin-walled pressure vessels dictate sheet-metal construction.

Ti-7Al-4Mo and Ti-6Al-6V-2Sn: Both of these grades are used for high-strength pressure vessels

Box Score on Titanium Pressure Vessels

Aerojet General Corp.
Ablestar, the first successful rocket engine to be restarted in space, uses three spherical titanium pressure bottles in the pressure-feed system.

Douglas Aircraft Co.
Five 22-in. diam titanium pressure vessels are used in the Saturn. Three operate at liquid-hydrogen temperature; two, at ambient temperature.

General Dynamics/Astronautics
The titanium pressure vessel was developed to a practical reality for the Atlas. The original stainless sphere for helium storage, weighing 205 lb, was replaced by a 79-lb titanium sphere.

General Dynamics/Fort Worth
Air-storage bottles, used in the B-58, are manufactured from annealed Ti-13V-11Cr-3Al. Bottles store 150 cu in. of air at 3000 psi, weigh 3.5 lb. Strength of units can be increased through heat treatment for further weight reduction.

Jet Propulsion Laboratory
Both the Ranger and Mariner space probes incorporate titanium vessels to store hydrazine and nitrogen in Midcourse Propulsion Units. JPL's titanium experience began with successful use of a fourth-stage titanium rocket-motor case in Pioneer IV.

Lockheed Missiles & Space Div.
From three to five titanium pressure vessels, depending on the program, are used in the Agena booster for helium storage. Samos and Midas projects also use Ti-6Al-4V pressure vessels.

Martin Co.
Four spherical titanium vessels, containing helium, furnish pressure for fuel and LOX systems in Titan. Two are used in each stage and are contained inside the LOX tank. Total weight saved: 150 lb.

North American Aviation
The largest titanium pressure vessel to date, a 96 in. long by 14-in. diam cylinder, is used in the X-15. This aircraft also uses three spherical vessels to pressure feed hydrogen peroxide to the engine, to pneumatically control propellant-system valves, and to purge the engine for restarts. The B-70 also uses a titanium pressure vessel—a 10-in. sphere, manufactured from Ti-7A1-4Mo, heat treated to 190,000 psi tensile strength.

operating at ambient temperatures. Both can be heat treated to tensile strengths of about 190,000 psi. Ti-6Al-6V-2Sn was first used in the Davy Crockett recoilless gun, while Ti-7Al-4Mo has been used for a 10-in. diam, 510-cu in. sphere for the B-70.

Design

Titanium pressure vessels are produced as spheres, cylinders, and ellipsoids, with most applications utilizing the efficient configuration of the sphere. Sizes in spheres range from 2¼ to 36 in. diam, but most production is in the 14 to 26 in. diam range. A current project includes design and fabrication of a torus-shaped assembly.

Burst Pressure/Working Pressure: Generally, titanium bottles are designed for working pressures of 45 to 50 per cent of burst strength for uses where the vessel is pressurized in the presence of personnel, and to about 75 per cent for other applications.

Compatibility: Titanium is immune to atmospheric corrosion, and is compatible with hydrogen, nitrogen, helium, hydrazine, and compressed air. Studies are now in progress to determine the metal's

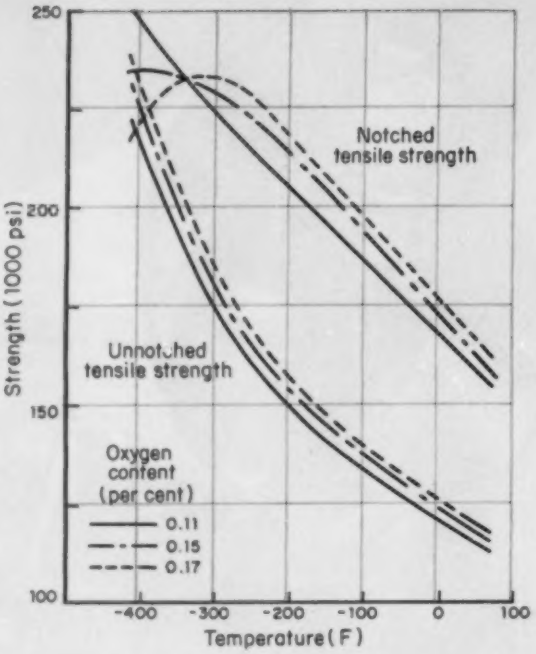


Fig. 1—Notched (K_t=6.3) and unnotched tensile strengths of Ti-5Al-2.5Sn at various temperatures. Specimens contained 0.02 per cent N, 0.03 per cent C; oxygen content, as shown. Sheet thickness was 0.040 in.

Table 1—Typical Mechanical Properties of Ti-6Al-4V
Machined Sections of Forgings and Bar Stock

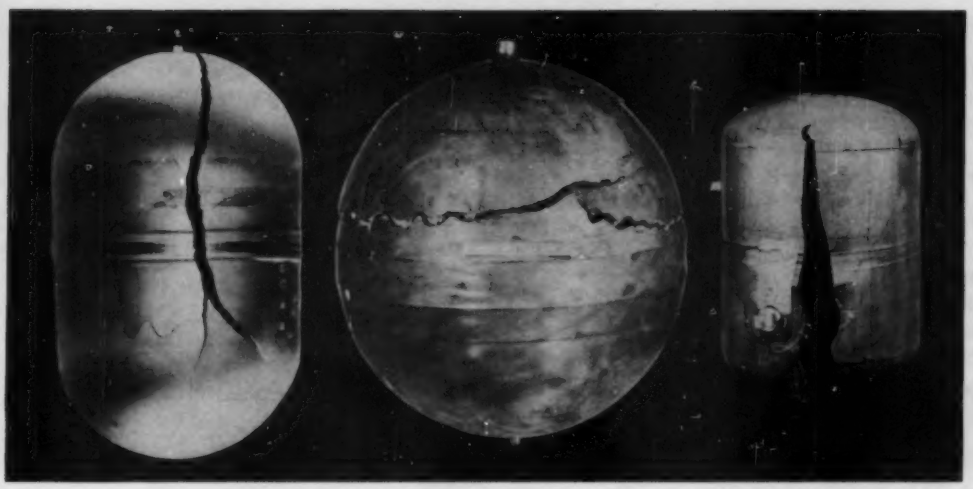
As-Received Thickness (in.)	Min Thickness as Heat Treated (in.)	Yield Strength, 0.2 Per Cent (1000 psi)	Tensile Strength (1000 psi)	Elongation in 4 Diam (per cent) L*	Elongation in 4 Diam (per cent) T†	Reduction in Area (per cent) L*	Reduction in Area (per cent) T†
3 to 5	3 to 5	125	135	9	7	20	15
	2 to 3	125	135	9	7	20	15
	1 to 2	135	145	9	7	20	15
	1 and under	145	155	9	7	20	15
2 to 3	2 to 3	135	145	11	9	25	20
	1 to 2	140	150	11	9	25	20
	1 and under	150	160	11	9	25	20
1 to 2	1 to 2	145	155	11	9	25	20
	1 and under	150	160	11	9	25	20
1 and under	1 and under	153	165	13	11	30	25

*Longitudinal test specimens taken from center of transverse dimensions.
†Transverse tests taken when size permitted.

Table 2—Typical Mechanical Properties of Ti-6Al-4V

Forging and Heat Treatment*	Temp (F)	Yield Strength (1000 psi)	Tensile Strength (1000 psi)	Elongation† (per cent)	Reduction in Area (per cent)	Notched UTS‡ (1000 psi)
Finish forged below 1700 F, air cooled	75	177	188	10.9	37.3	...
Solution treated, 1730 F, 1 hr; water quenched, 1050 F, 3 hr; air cooled	−320	238	263	8.7	33.9	264

*Forged to 0.75 in. thick section.
†Standard 0.252-in. diam tensile specimen, 1.0-in. gage length.
‡Notched tensile specimen 0.363-in. diam, circumferentially notched to 0.290-in. diam; 60-deg notch; root radius = 0.0025 in.; K_t = 6.3.
Data, courtesy General Dynamics/Astronautics.



Burst failures in titanium pressure vessels occur in casing walls, and cracks travel across welds, indicating the ductile nature of the materials. Vessel at far left is Ti-14V-11Cr-3Al; others, Ti-6Al-4V.

compatibility with other fuels and gases employed in missile operation.

Testing

The "proof test" is the foundation of a testing program developed to guarantee the efficiency of pressure vessels in general. All vessels are proof tested before use in an airborne assembly.

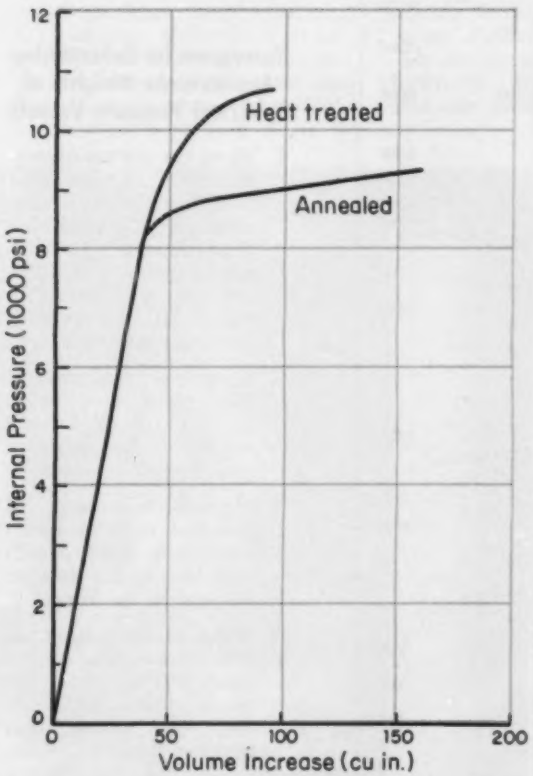


Fig. 2—Volume increase versus test pressure of Ti-6Al-4V vessels. Initial volume of 17 in. OD spheres is 2061 cu in. Ends of curves indicate burst pressures.

One producer's test program follows these procedures:

- All vessels are pressurized to 5000 psi four times. Pressures are held for periods up to three minutes with the assemblies submerged in liquid nitrogen.
- Every fiftieth bottle is pressurized to 9500 psi in liquid nitrogen for one minute, then burst at room temperature. In a series of 16 tests representing 500 vessels, the average burst pressure was 7070 psi, with a total range of 6900 to 7200 psi.

Liquid-nitrogen temperatures are employed since the inherently greater notch sensitivity of materials under cryogenic conditions reveals minute defects. Some organizations proof test in liquid nitrogen even when bottles are designed for ambient-temperature operation.

The principal measurement in proof testing is volume increase of the vessel during the holding periods. This increase should, of course, be very low. Fig. 2 shows increase of volume with internal pressure for representative titanium pressure vessels.

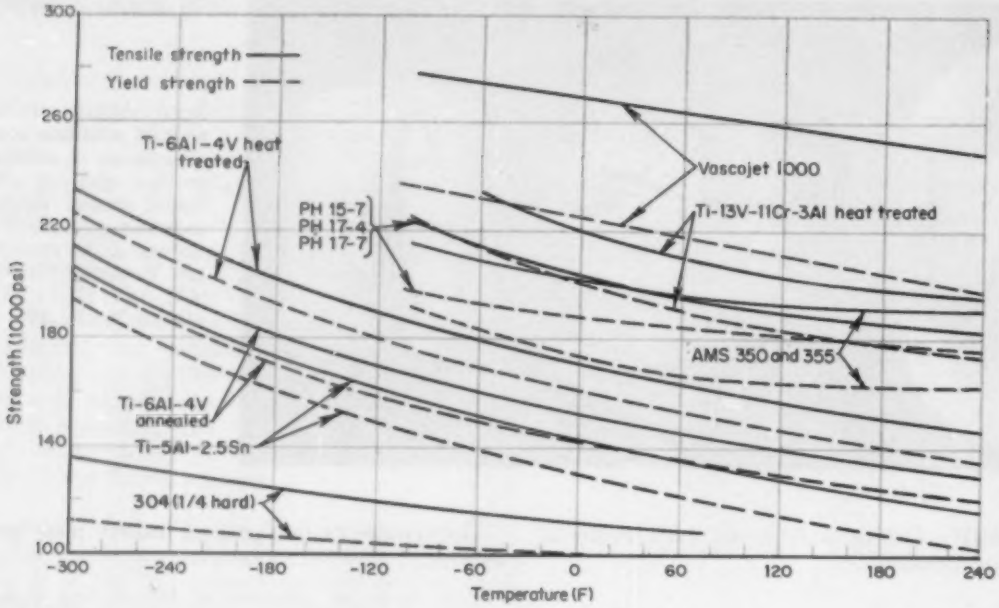
Fabrication

The titanium pressure-vessel program, initiated in mid-1957, aimed development efforts at drawing

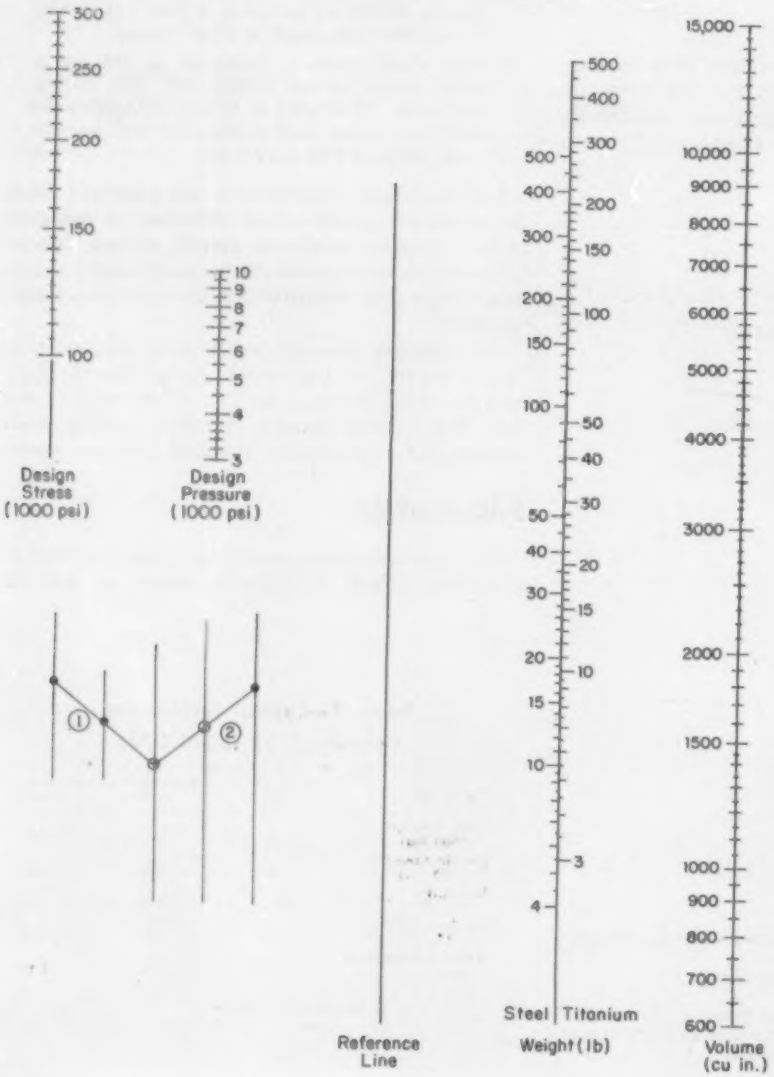
Table 3—Typical Mechanical Properties* of Ti-5Al-2.5Sn

Property	Temperature (F) 70	−320	−423
Yield Strength (1000 psi)	102	168	206
Tensile Strength (1000 psi)	112	181	229
Elongation (per cent)	16.5	16.0	15.0
Notched UTS† (1000 psi)	155	228	263
Notched/Unnotched Ratio	1.38	1.26	1.10

*All tests on longitudinal specimens.
†K_t = 6.3.



Strength versus temperature for various steel and titanium alloys. Strength levels shown are based on heat-treat compromises between maximum strength and ductility for each material.



Nomogram for Determining Approximate Weights of Spherical Pressure Vessels

1. Using the curves above, determine allowable design strength of the selected material by applying a suitable safety factor to the tensile or yield-strength value at the critical service temperature.
2. Enter the nomogram at the left, and draw a line through the known values of design stress and design pressure.
3. From the intersection of this line with the reference line, draw a second line to the desired volume of the vessel.
4. Read shell weight at the intersection of the second line with the weight scale. Add 5 per cent for bosses and welded joints.

plate into hemispheres. Bosses and trunnions were welded to the hemispheres which were then joined.

This approach has given way to use of forged hemispheres with integrally forged bosses and trunnions. This method overcomes the major problem inherent in the design of the original spheres—premature failure at boss and trunnion welds, caused by triaxiality introduced during pressure loading, with consequent bending moments in the lower-ductility welds.

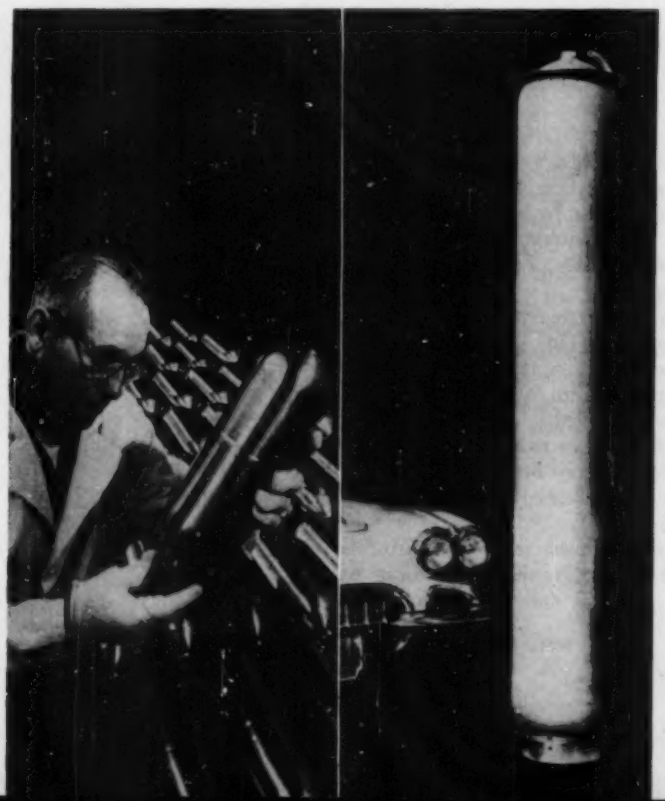
Forging: Standard forging techniques are employed in production of pressure-vessel parts containing bosses, trunnions, and nozzle ports. After being forged, parts are rough machined. Sufficient stock is left to assure subsequent removal of surface contamination from high-temperature heat treatment. For the alpha-beta alloys, Ti-6Al-4V and Ti-7Al-4Mo, heat treatment consists of a solution treatment at 1650 to 1750 F, followed by a water quench.

Table 4—Cost of Ti-6Al-4V Billet

1955	10.50
1956	9.10
1957	7.95
1958	7.10
1959	4.90
1960	3.75
1961 (Sept. 15)	3.00

*Costs are in dollars per lb, as of January 1, except as indicated.

Largest titanium pressure vessel in service, right, is a 96 in. long, 12,280 cu in., helium-storage tank which pressure feeds LOX and ammonia to the X-15 engine. Material is Ti-6Al-4V alloy. Representative of smaller vessels are the 4¾ in. diam, 14 in. long, beta-titanium units shown at left. These vessels store air at 3000 psi and are used in the escape capsule of the B-58.



Welding: Both fusion welding and pressure welding are employed in the manufacture of titanium pressure vessels. When fusion welding is used, standard titanium welding practices must be observed to protect the weld area from atmospheric contamination.

Filler wire should be either commercially pure titanium or be material of the same composition as the base metal. Design of welded joints must compensate for any strength dilution caused by the softer commercially pure wire, and/or the fact that the weld joint (particularly a fusion-welded joint) is annealed rather than heat treated. It is generally sounder practice to make the weld flange heavier (imposing a slight weight penalty) than to attempt to solution treat a coarse, dendritic weld structure.

After welding, the vessel is aged at a temperature consistent with the metallurgical characteristics of the alloy (800 to 1100 F). Beside aging of the solution-treated material, this process stress relieves the weld. However, with the beta grade alloy (Ti-13V-11Cr-3Al) welding is done after final heat treatment.

Pressure welding entails heating the sections to a temperature slightly below the beta transus, then forcing the sections together under pressure. Because a finer grain size is inherent in a pressure weld (properties are near those of forged parts), the final assembly can be solution treated and aged.

Machining: In rough machining operations, surface finish can be maintained under 100 mu in., and wall thickness controlled to ±0.005 in. Tolerances on machined bosses can be held to ±0.010 in.

Sheet Metal: Despite the fact that most titanium pressure vessels now in service have been manufactured from forged sections, both plate and sheet construction show promise for fabrication of large, thin-wall vessels.

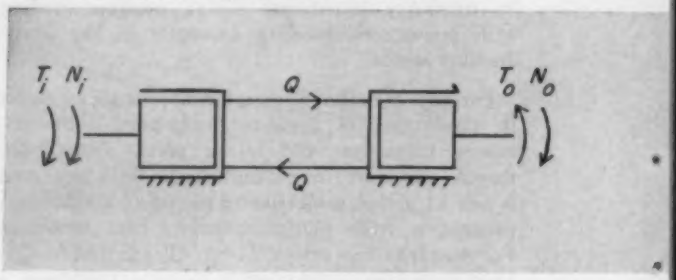
Titanium-alloy plate and sheet can be drawn and spun on equipment used for steel parts. In general, drawing and spinning are performed hot (800 to 1300 F). However, the beta-titanium alloy can be drawn cold. Availability in strip length and good formability make Ti-13V-11Cr-3Al feasible for on-site fabrication of large-diameter parts. However, a problem arises here which must be considered. When large section-size differences exist (nozzle ports, trunnions, and girth weld flanges), bending moments induced during pressure application may cause premature failure of a vessel at the welds if these factors are not considered in design.

Costs

Titanium first went into service when its cost was about six times that of high-alloy steel on a volume basis. Titanium fabrication costs were about three times those of 4340. Raw material costs have been reduced to the present $3 per lb, Table 4.

Even more significant is the fact that fabrication costs are now, in many cases, nearly the same as those for nickel-bearing or PH steels.

Fig. 1—Pure hydraulic hydrostatic transmission.



HYDROSTATIC TRANSMISSIONS

A compact engineering course covering

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Chairman
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ESSENTIALLY, a hydrostatic transmission is composed of two interconnected positive-displacement hydraulic elements—a pump and a motor. In contrast, a hydrodynamic transmission consists basically of a centrifugal pump and a reaction turbine.

The schematic system to be used in this article is detailed in Fig. 1 and 2. The pump or motor is represented by a rotor and a housing. Shafts can be connected to rotor or housing, either of which can be grounded. To obtain pumping action, there must be relative motion between rotor and housing. Relative motion between hydraulic lines and the housing is indicated as a fluid analog of a slip ring, Fig. 2.

In the simplest form of hydrostatic transmission, Fig. 1, the hydraulic output of a positive-displacement pump is delivered to a positive-displacement

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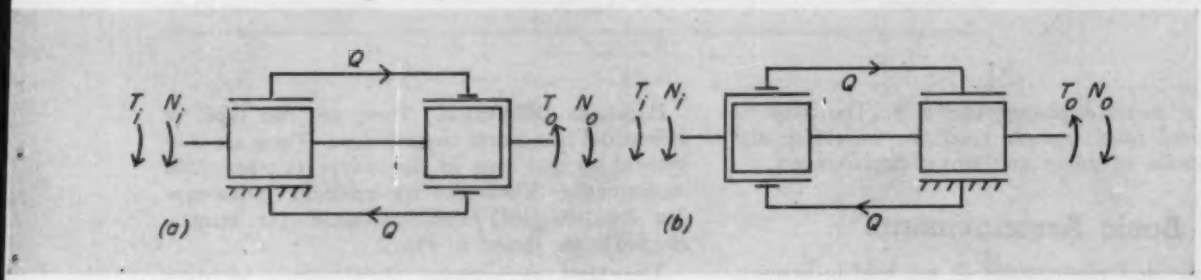
Fig. 2—Hydraulic diferential hydrostatic transmissions, split torque, *(a)*, and split speed, *(b)*.



Fundamental Relationships

Round-Up of Basic Arrangements

Evaluation Techniques

Performance Prediction

Practical Example

motor. Both pump and motor are mechanically connected to the ground. The pump shaft is connected to the driving motor and the hydraulic-motor shaft is connected to the load. The pump and motor can be of the piston, vane, gear, or lobe type.

The performance characteristics of this pure hydraulic transmission, frequently called the "straight hydrostatic," have been discussed in considerable detail.[1] These characteristics are summarized in Table 1 and Fig. 3 for the ideal transmission, which has no energy losses. These curves are based upon the ideal performance equations of pump and motor:

$$Q = DN \tag{1}$$

and

$$T = \frac{\Delta P D}{2\pi} \tag{2}$$

Since the entire flow from the pump is supplied to the motor, $D_p N_p = D_m N_m$, or $N_m/N_p = D_p/D_m$. Subscript p indicates pump parameters and subscript m indicates motor parameters.

From Equation 2,

$$T_m = \frac{\Delta P D_m}{2\pi} \tag{3}$$

and

$$T_p = \frac{\Delta P D_p}{2\pi} \tag{4}$$

Since the pressure is common to pump and motor, Equations 3 and 4 can be combined and rearranged to $T_p/T_m = D_p/D_m$. Further substitution yields

$$\frac{T_p}{T_m} = \frac{N_m}{N_p} \tag{5}$$

The ratio of ouput speed N_m to input speed N_p is a linear function of the ratio of pump displace-

[1]References are tabulated at end of article.

Table 1—Performance Characteristics

Type of Motor	Type of Pump: Fixed Displacement	Type of Pump: Variable Displacement
Fixed Displacement	$N_m/N_p = D_p/D_m = \text{Constant}$ $T_m/T_p = D_m/D_p = \text{Constant}$	$0 < N_m/N_p < D_{pm}/D_m$ $D_m/D_{pm} < T_m/T_p < \infty$
Variable Displacement	$D_p/D_{mm} < N_m/N_p < \infty$ $0 < T_m/T_p < D_{mm}/D_p$	$0 < N_m/N_p < \infty$ $0 < T_m/T_p < \infty$

ment to motor displacement, Fig. 3. The range of the speed ratio depends upon the variability and magnitudes of pump and motor displacements.

Basic Arrangements

These ideal relationships do not hold in practice, because pumps and motors are subject to slip and frictional torque. As a result, transmission efficiencies have frequently been very low. Various methods to improve efficiency have been devised.

Nomenclature

C_d = Coefficient of viscous drag
C_f = Coefficient of dry friction
C_s = Coefficient of slip
C_{dm} = Coefficient of viscous drag of motor
C_{dp} = Coefficient of viscous drag of pump
C_{fm} = Coefficient of dry friction of motor
C_{fp} = Coefficient of dry friction of pump
C_{sm} = Coefficient of slip of motor
C_{sp} = Coefficient of slip of pump
D = Displacement volume per shaft revolution, cu ft per revolution
D_i = Displacement of input unit, cu ft
D_m = Displacement of motor, cu ft
D_{mm} = Maximum displacement of motor, cu ft
D_o = Displacement of output unit, cu ft
D_p = Displacement of pump, cu ft
D_{pm} = Maximum displacement of pump, cu ft
D_R = Ratio of pump displacement to motor displacement
D_{Rm} = Ratio of maximum pump displacement to motor displacement
g_1, g_2 = Gear ratios
N = Shaft speed, rps
N_i = Input-shaft speed, rps
N_m = Motor-shaft speed, rps
N_o = Output shaft speed, rps
N_p = Pump-shaft speed, rps
N_R = Ratio of motor speed to pump speed
N_1 = Sun-gear speed, rps
N_3 = Ring-gear speed, rps
N_4 = Spider speed, rps
Δp = Pressure differential across pump and motor, psf
Q = Flow rate, cfs
Q_m = Motor flow rate, cfs
Q_p = Pump flow rate, cfs
r_1 = Sun-gear radius, in.
r_2 = Planet-gear radius, in.
T_i = Input torque, lb-ft
T_o = Output torque, lb-ft
T_m = Hydraulic-motor torque, lb-ft
T_p = Hydraulic-pump torque, lb-ft
T_R = Ratio of motor torque to pump torque
μ = Viscosity of fluid, lb-sec per sq ft

Hydraulic Differential: There are two types of differential hydrostatic transmissions. These are constructed so that part of the energy is transmitted mechanically. These two transmissions, split-torque (or input-coupled) and split-speed (or output-coupled), are shown in Fig. 2.

The ideal performance characteristics of these differential transmissions are described by these equations:

For split torque,

$$\frac{N_o}{N_i} = 1 + \frac{D_i}{D_o} \tag{6}$$

and

$$\frac{T_o}{T_i} = \frac{1}{1 + \frac{D_i}{D_o}} \tag{7}$$

For split speed,

$$\frac{N_o}{N_i} = \frac{1}{1 + \frac{D_o}{D_i}} \tag{8}$$

and

$$\frac{T_o}{T_i} = 1 + \frac{D_o}{D_i} \tag{9}$$

If the unit with displacement D_i is variable and this displacement is made zero, flow Q will be zero and all torque will be transmitted mechanically. Thus, input and output speed will be the same. The transmission is then "locked up." This ideal relationship would be true if there were no slip or frictional drag in either unit.

SPLIT TORQUE: Assume the variable pump on the left, Fig. 2(*a*), to be in zero-displacement position, with the electric motor driving the input shaft. Since the housing is stationary, there is a differential speed, N_i, between the rotor and housing. This speed will produce pumping at the rate, $Q = D_iN_i$. However, since D_i is zero, no pumping occurs, and the delivery is zero.

Since there is no hydraulic input to the right-hand unit, there is no relative motion of rotor and housing. The output shaft must turn at the speed of the rotor, N_i.

If D_i is increased to some finite value, the left-hand unit pumps at the rate, $Q = D_iN_i$. The right-hand unit receives the flow. To accommodate this flow, the hydraulic motor must run with a differential speed between rotor and housing. The output speed exceeds the input speed by an amount $(D_i/D_o)N_i$. The output speed can be increased above input speed until D_i is a maximum.

SPLIT SPEED: The split-speed transmission is similar to the split-torque device, but the ratios of speed

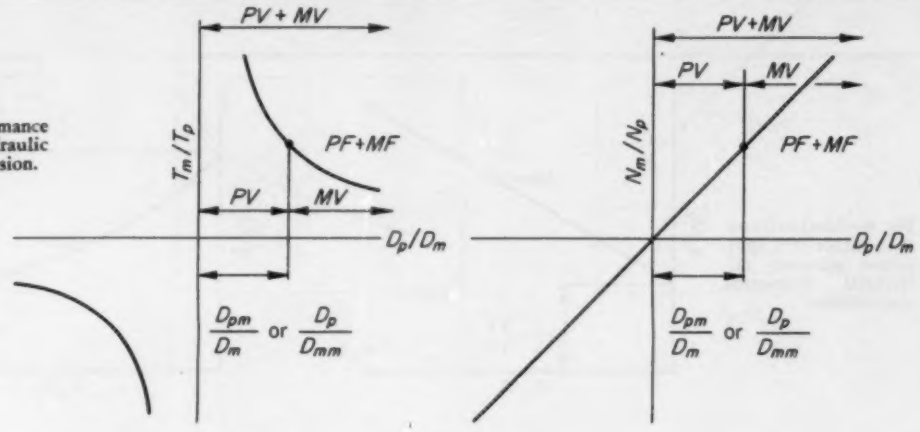


Fig. 3—Ideal-performance curves of a pure hydraulic hydrostatic transmission.

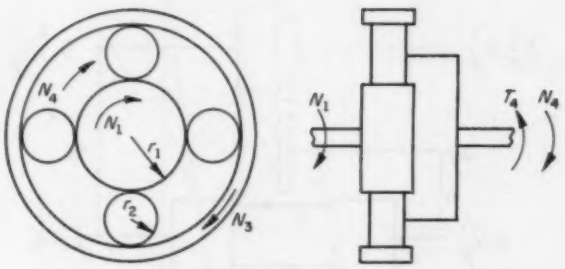


Fig. 4—Simple planetary gear system.

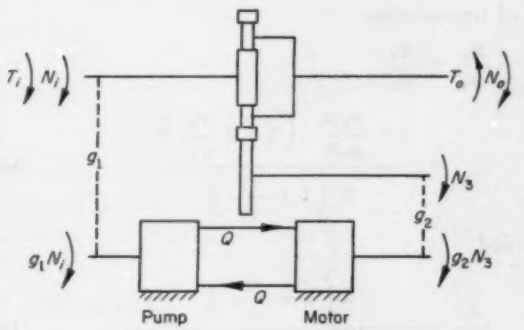


Fig. 5—Split-torque planetary differential hydrostatic transmission.

and torque are different, due to the mechanical and hydraulic linkages.

Performance of such transmissions is, in principle, the same as that of the ideal transmission, but the efficiency is much less than 100 per cent and, under certain circumstances, may be very low.

Planetary Differential: Operating characteristics similar to those of the hydraulic differential hydrostatic transmission can be obtained by introducing a planetary gear train into the transmission circuit. This planetary-differential transmission has the same general operating characteristics as the hydraulic-differential transmission. In addition, it is somewhat easier to build.

In the simple planetary gear system, Fig. 4, the four planet gears are interconnected by a spider which is connected to a single shaft. From the kinematics of the operation of the system[3]

$$\frac{N_4}{N_1} = \frac{1 + \left(1 + 2\frac{r_2}{r_1}\right)\frac{N_3}{N_1}}{2\left(1 + \frac{r_2}{r_1}\right)} \qquad (10)$$

There is a very simple relationship between sun-gear speed N_1, ring-gear speed N_3, and the speed of the spider connecting the planets, N_4, as well as the ratio of the diameter of the planet gear to the sun gear.

SPLIT TORQUE: This type of transmission consists of a variable positive-displacement pump and a constant positive-displacement motor, interconnected with a planetary gear train, Fig. 5. The summation of all external torques on the system must be zero. Thus,

$$T_i - T_o - T_p + T_m = 0 \qquad (11)$$

If this transmission is an ideal one with no energy losses,

$$T_iN_i = T_oN_o \qquad (12)$$

Since the output of the pump is delivered directly without loss to the hydraulic motor,

$$\frac{g_1N_i}{g_2N_3} = \frac{D_o}{D_i} \qquad (13)$$

Equations 10 through 13 can be combined and rearranged to describe the operation of this type

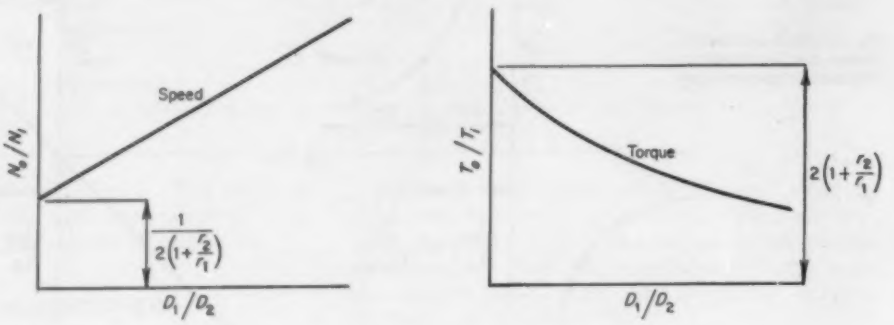


Fig. 6—Ideal-performance curves of a split-torque planetary differential hydrostatic transmission.

of transmission.

$$\frac{N_o}{N_i} = \frac{N_4}{N_1} = \frac{1+\frac{g_1 D_i}{g_2 D_o}\left(1+2\frac{r_2}{r_1}\right)}{2\left(1+\frac{r_2}{r_1}\right)} \quad (14)$$

and

$$\frac{T_o}{T_i} = \frac{2\left(1+\frac{r_2}{r_1}\right)}{1+\frac{g_1 D_i}{g_2 D_o}\left(1+2\frac{r_2}{r_1}\right)} \quad (15)$$

Equations 14 and 15 are plotted in Fig. 6. Since the relationship between the speed ratio and the displacement ratio is comparable to that of Equation 6, this type of planetary transmission can be designated a split-torque transmission. The equations for the two types of transmissions differ only in the fact that Equations 14 and 15 include a ratio due to the diameter ratios associated with the various gears.

Split Speed: A planetary-type hydrostatic transmission analogous to the split-speed differential transmission is shown in Fig. 7. Analysis of the kinematics and dynamics of the system yields:

$$\frac{N_o}{N_i} = \frac{N_4}{N_1} = \frac{1}{2\left(1+\frac{r_2}{r_1}\right)+\left(1+2\frac{r_2}{r_1}\right)\frac{g_2 D_o}{g_1 D_i}} \quad (16)$$

and

$$\frac{T_o}{T_i} = 2\left(1+\frac{r_2}{r_1}\right)+\left(1+2\frac{r_2}{r_1}\right)\frac{g_2 D_o}{g_1 D_i} \quad (17)$$

Equations 16 and 17 are plotted in Fig. 8. Since the relationship between the torque ratio and the displacement ratio is analogous to Equation 13, this type of planetary transmission can be designated a split-speed transmission.

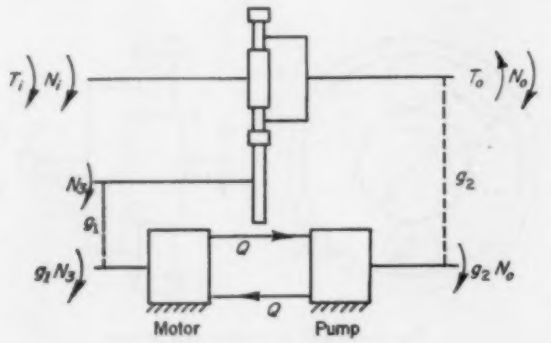


Fig. 7—Split-speed planetary differential hydrostatic transmission.

Operating Principles: Assume that the variable pump, Fig. 5, is in the zero-displacement position. The planetary-gear input shaft speed is N_4. The pump shaft turns at speed $g_1 N_4$. Since there is no pump displacement, the pump produces no hydraulic output to be delivered to the motor. Thus, the motor shaft does not rotate and speed N_3 is zero. The ring gear of the planetary gear train is stationary. The sun gear rotates at input speed N_4. The planetary gears rotate with the spider producing speed $N_4 = N_o$, the output speed. The ratio between output speed and input speed is determined entirely by the ratio of the gear diameters. In effect, a straight mechanical planetary-gear transmission is produced.

If the displacement of the variable pump is increased to some positive value and the hydraulic output delivered to the motor, the motor shaft will rotate at speed $g_2 N_3$. This shaft in turn rotates the ring gear at a corresponding speed, N_3. With the ring gear rotating, the output speed of the spider is different from input speed N_4. The output speed

Fig. 8—Ideal-performance curves of a split-speed planetary differential hydrostatic transmission.

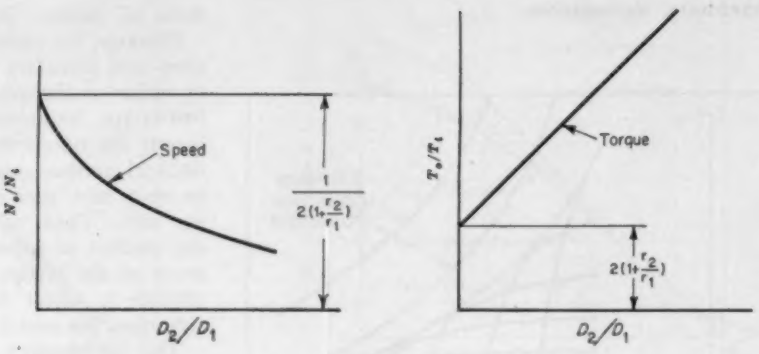
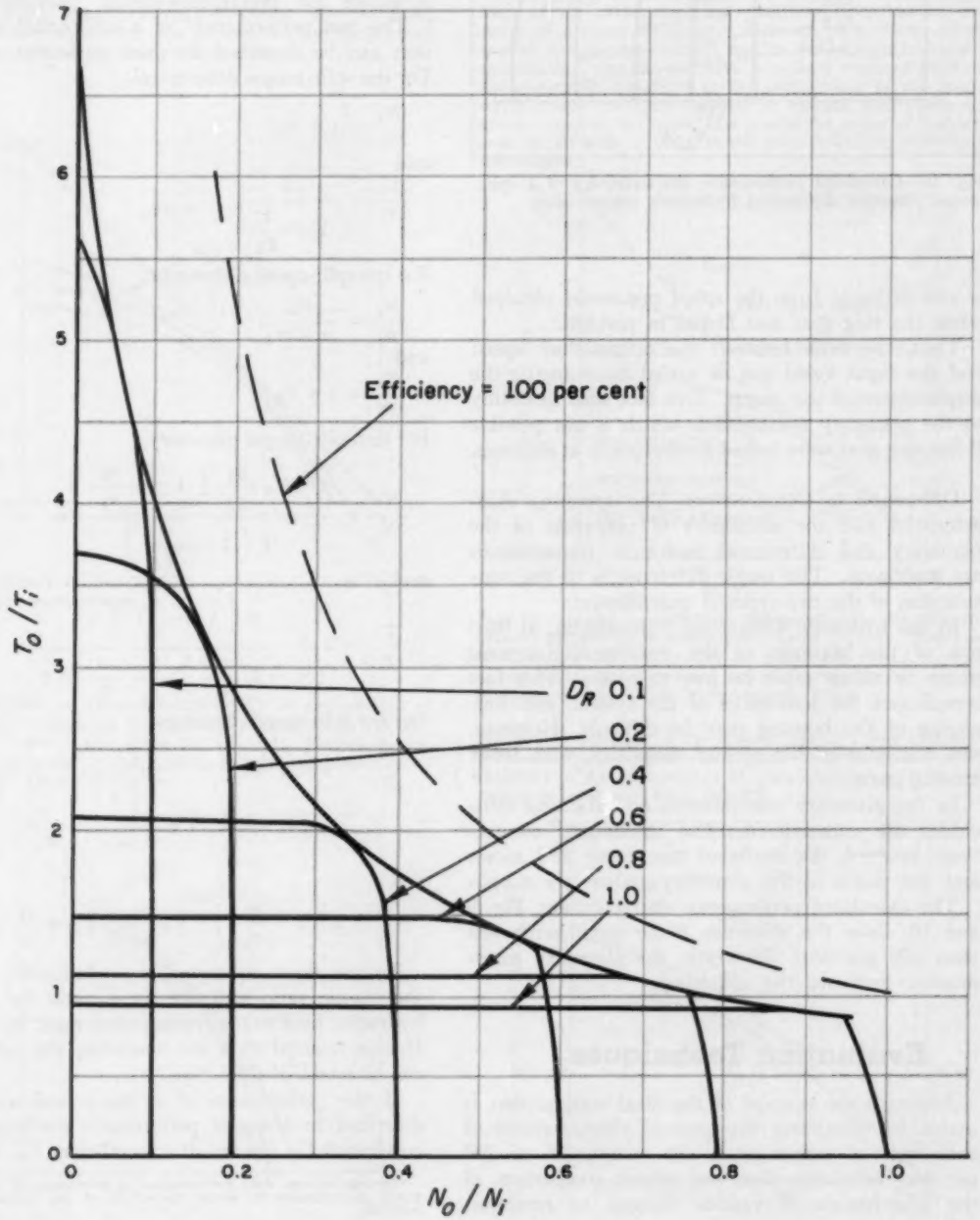


Fig. 9 — Calculated performance characteristics of a pure hydraulic hydrostatic transmission.



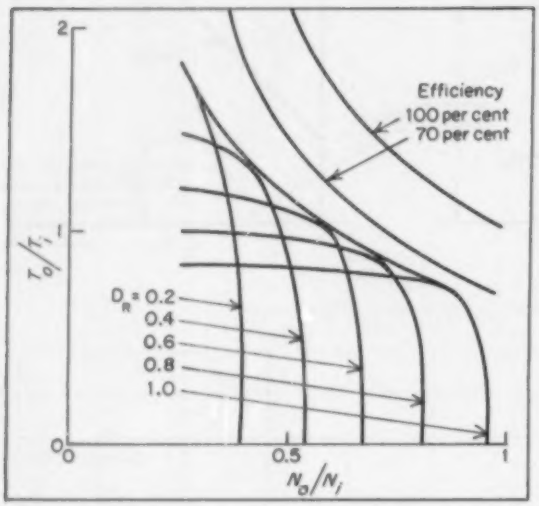


Fig. 10—Calculated performance characteristics of a split-torque planetary differential hydrostatic transmission.

is also different from the speed previously obtained when the ring gear was locked in position.

Thus, the ratio between the output-shaft speed and the input speed can be varied by changing the displacement of the pump. This fact adds flexibility to the planetary transmission which is not possible if the ring gear were locked mechanically at all times.

Differences in Construction: The operating characteristics and the mechanics of operation of the planetary and differential hydraulic transmissions are analogous. The major difference is in the construction of the two types of transmission.

In the hydraulic differential transmission, at least one of the housings of the positive-displacement pump or motor must be free to rotate. This fact complicates the hydraulics of the system, and balancing of the housing may be difficult. However, this transmission has greater simplicity, with fewer moving parts.

In the planetary transmission, no balancing difficulties are encountered. The mechanical connections between the shafts of the pump and motor and the shafts of the planetary system are simple.

The calculated performance characteristics, Fig. 9 and 10, show the efficiency to be significantly less than 100 per cent. However, the planetary transmission increases the efficiency.

Evaluation Techniques

Although the concept of the ideal transmission is useful in visualizing the general characteristics of each type of transmission, the assumption of 100 per cent efficiency does not permit comparison of the effectiveness of various designs, or combinations of pumps, motors, and gear trains.

However, the performance of differential transmissions and planetary transmissions can be described in terms of the performance of a pure hydraulic hydrostatic transmission. The equations presented permit the comparison and evaluation of combinations of various qualities and sizes of components. In each case, gear efficiency is assumed to be 100 per cent. Thus, only the hydraulic elements and the method of interconnecting the various components of the system are compared. However, it is possible to adjust the equations to take into consideration the actual efficiency of the gear trains.

The performance characteristics of a pump or motor can be described in terms of performance coefficients with sufficient accuracy to predict performance for preliminary-design purposes.[3]

The real performance* of a differential transmission can be described by these equations:
For the split-torque differential,

$$\frac{N_o}{N_i} = 1 + N_R \tag{18}$$

and

$$\frac{T_o}{T_i} = \frac{1}{1 + \frac{1}{T_R}} \tag{19}$$

For the split-speed differential,

$$\frac{N_o}{N_i} = \frac{N_R}{1 + N_R} \tag{20}$$

and

$$\frac{T_o}{T_i} = 1 + T_R \tag{21}$$

For the split-torque planetary,

$$\frac{N_o}{N_i} = \frac{1 + N_R \frac{g_1}{g_2}\left(1 + 2\frac{r_2}{r_1}\right)}{2\left(1 + \frac{r_2}{r_1}\right)} \tag{22}$$

and

$$\frac{T_o}{T_i} = \frac{2\left(1 + \frac{r_2}{r_1}\right)}{\left(1 + 2\frac{r_2}{r_1}\right)\frac{g_1}{g_2}\frac{1}{T_R} + 1} \tag{23}$$

For the split-speed planetary,

$$\frac{N_o}{N_i} = \frac{1}{2\left(1 + \frac{r_2}{r_1}\right) + \frac{\left(1 + 2\frac{r_2}{r_1}\right)\frac{g_2}{g_1}}{N_R}} \tag{24}$$

and

$$\frac{T_o}{T_i} = 2\left(1 + \frac{r_2}{r_1}\right) + T_R \frac{g_2}{g_1}\left(1 + 2\frac{r_2}{r_1}\right) \tag{25}$$

To use these equations, the relationship between the torque ratio and the speed ratio for the pure hydraulic hydrostatic transmission must be obtained. If experimental data are available, the relationship can be established readily.

If the performance of a pump and a motor is described in terms of performance coefficients (slip coefficient C_s, viscous-drag coefficient C_d, and dry-

*In this article, real performance is considered to be the predicted performance in which the effect of the various losses is included.

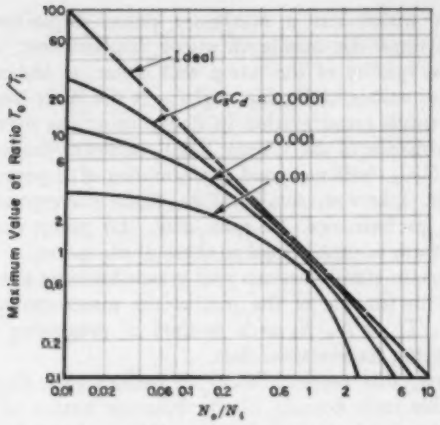


Fig. 11—Effect of performance coefficients. The best pump and motor are described by the smallest value of the product, C_pC_d. In each of the four cases, $C_f=0$.

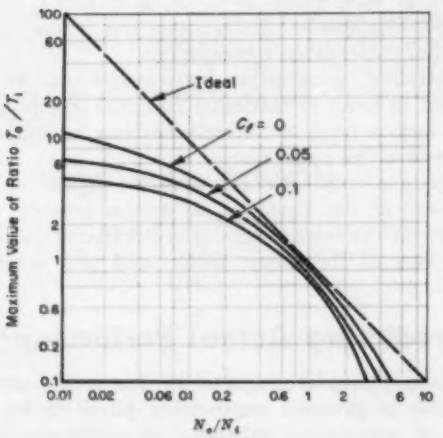
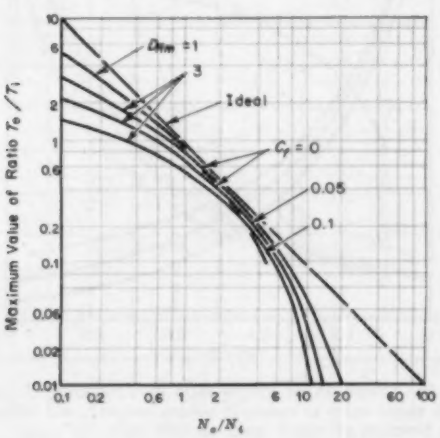


Fig. 12—Effect of dry friction coefficient C_f on over-all transmission performance.

Fig. 13—Effect of various values of C_f on performance of a hydraulic hydrostatic transmission with $D_{Rm}=3$. A performance curve is also given for $D_{Rm}=1$. Maximum efficiency in each case is comparable, but the maximum occurs at different values of N_o/N_i.



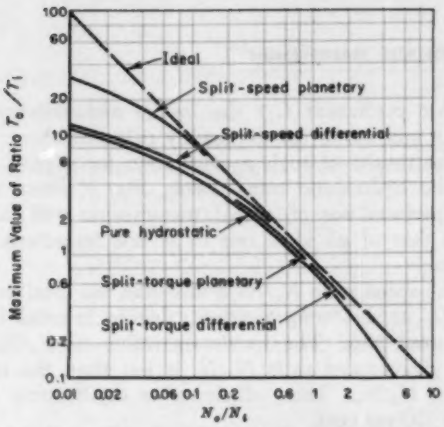


Fig. 14—Pure hydrostatic transmission compared with the various types of differential and planetary transmissions. Each of the differential and planetary types has its own range of greatest efficiency. Although performance of the special transmissions exceed that of the straight hydrostatic transmission, they do not have as wide a range of performance. Greater flexibility in the performance of the special transmissions could be obtained by making both pump and motor variable, but in no case would the range of performance be as wide as that of the pure hydraulic hydrostatic transmission.

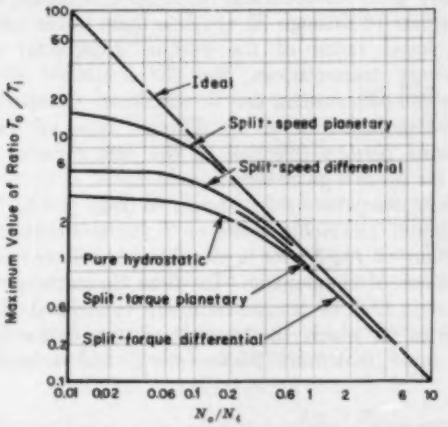
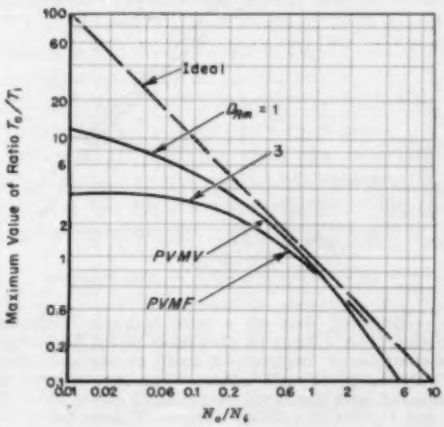


Fig. 15—Special transmissions compared with the pure hydraulic hydrostatic transmission. Ratio $D_R=3$. The general trend is the same as for the pump and motor of equal displacement, but the more complex transmissions do not perform as well in the higher speed ranges.

Fig. 16—Comparison of the performance of a pure hydraulic hydrostatic transmission with $D_R=1$, (both pump and motor variable) to the performance of a transmission with $D_R=3$, (variable pump and fixed motor).



friction coefficient C_f) the torque and delivery of pump and motor can be readily calculated.[4]

The results of such a calculation for a pure hydraulic hydrostatic transmission, Fig. 9, show that the performance of a real transmission will differ from that of an ideal one in several important respects.

The speed ratio N_o/N_i is less than the ideal value D_1/D_2 at zero torque output, due to internal friction and slip. The maximum value of T_o/T_i at any given speed ratio N_o/N_i is less than the ideal value, N_i/N_o. Thus, efficiency is significantly less than 100 per cent.

The maximum torque ratio, at $N_o/N_i = 0$, is a finite value, rather than infinite as would be expected for an ideal frictionless transmission, due to friction and slip in both pump and motor. The curves indicate that there is an envelope which defines the maximum possible torque ratio at any given speed ratio for a particular transmission.

Using the relationship between T_o/T_i and N_o/N_i for any given combination of pump and motor, and Equations 18 through 25 to relate these to the torque and speed ratios of the various differential and planetary transmissions, the characteristics of the more complex systems can be described. Comparison of the performance of the different types of transmissions permits selection of the best type of device for use in a given service.

Such comparisons are shown in Fig. 11-16. The maximum attainable value of T_o/T_i is shown as a function of N_o/N_i for a number of different combinations of components. In these comparisons two different sizes of transmission are considered—first, a series in which the pump and the motor have the same maximum displacement, and second, a series which has a maximum pump displacement three times the maximum motor displacement.

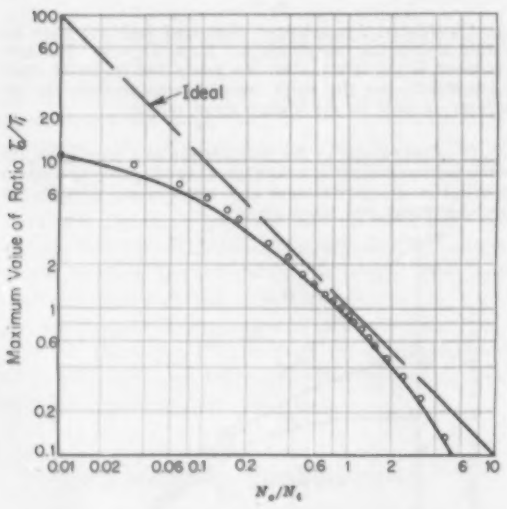


Fig. 17—Measured data on a pure hydraulic hydrostatic transmission with a ratio of maximum pump displacement to maximum motor displacement equal to one and employing a variable pump and motor. The experimental data are compared with predicted performance based on $C_sC_d = 0.0001$ and $C_f = 0.057$. (Data courtesy Vickers Inc.)

The quality of the pump and motor, as indicated by the values of C_s, C_d, and C_f, is the most important single consideration in determining the over-all performance of the system. Small values of the product, C_sC_d, indicate good performance of a pump or motor. Likewise, small values of C_f correspond to good performance. In each case, the pump coefficients are assumed equal to those of the motor.

Certain simplifications and generalizations are implicit in the use of the plot of the maximum value of T_o/T_i vs N_o/N_i as a method of presenting and analyzing transmission data.

First, this representation of performance data is possible only because of the inherent nature of the positive-displacement elements. When these characteristics are expressed in terms of a suitable mathematical model, both pressure and viscosity can be eliminated as parameters.

Secondly, the existence of a maximum value of T_o/T_i at each value of N_o/N_i is inherent in the positive-displacement mechanisms and in the mathematical model of the transmissions.

Therefore, transmission performance can be described in terms of maximum potential performance, and various types of transmissions can be compared in terms of this performance.

The maximum efficiency does not depend on the viscosity of the liquid or on system pressure, but rather on the relationships of the performance characteristics of the pump, motor, and gear arrangement.

Predicting Actual Performance

These principles discussed in this article can be applied to practical engineering problems by the use of appropriate equations to calculate output torque under various conditions. These equations for the pure hydraulic hydrostatic transmission with variable pump and fixed motor are:

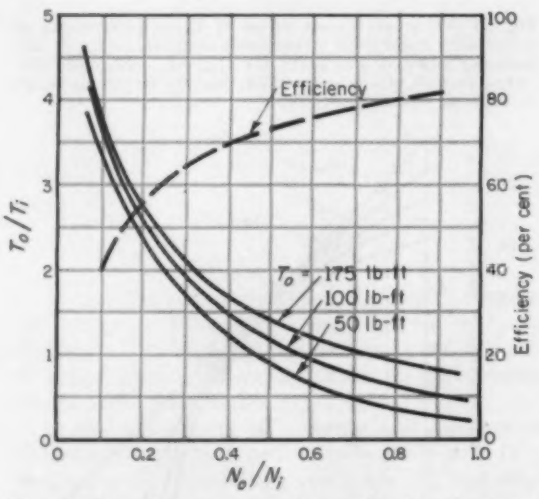


Fig. 18—Output-input torque ratio as a function of output-input speed ratio at constant torque output; and efficiency as a function of speed ratio at 1500 psi.

$$T_p = \frac{(\Delta p D_p) + (C_f \Delta p D_{pm})}{2\pi} + C_{dp}\mu N_p D_{pm} \quad (26)$$

$$T_m = \frac{\Delta p D_{mm}}{2\pi}(1 - C_{fm}) - C_{dm}\mu N_m D_{mm} \quad (27)$$

$$T_m = \frac{\Delta p D_{mm}}{2\pi}\left[(1 - C_{fm}) - \frac{C_{dm} N_R (C_{sm} + C_{sp} D_{Rm})}{D_R - N_R}\right] \quad (28)$$

$$T_m = \mu N_p D_{mm}\left[\frac{(1 - C_{fm})(D_R - N_R)}{C_{sm} + C_{sp} D_{Rm}} - C_{dm} N_R\right] \quad (29)$$

$$Q_p = D_p N_p - \frac{C_{sp} D_{pm} \Delta p}{2\pi\mu} \quad (30)$$

$$Q_m = D_m N_m + \frac{C_{sm} D_{mm} \Delta p}{2\pi\mu} \quad (31)$$

$$\Delta p = 2\pi\mu N_p \frac{D_R - N_R}{C_{sm} + C_{sp} D_{Rm}} \quad (32)$$

The information contained in Fig. 11-16 can be used as a basis for making a selection among the various types of transmissions for a particular application. However, after a type of transmission has been chosen, the details of its performance must be calculated.

Practical Example

An output torque of 175 lb-ft at 2900 rpm is required from a pure hydraulic hydrostatic transmission with the following characteristics: $D_{Rm} = 1$, $C_{sp} = C_{sm} = 10^{-8}$, $C_{dp} = C_{dm} = 10^{5}$, $C_{fp} = C_{fm} = 0.05$, viscosity = 15 centipoises, and pump speed = 3000 rpm.

The performance characteristics of the transmission are shown in Fig. 9, and are based upon calculations using Equations 26, 27, 30, and 31.

SOLUTION: Ratio $N_o/N_i = 2900/3000 = 0.966$. Assume $D_R = D_{Rm} = 1$. From Fig. 9, $T_R = 0.65$. Substituting in Equation 31,

$$\Delta p = 2\pi(15)(2.088 \times 10^{-5})\left(\frac{3000}{60}\right)\left(\frac{1 - 0.966}{10^{-8} + 10^{-8}}\right)$$
$$= 216{,}000 \text{ psf}$$
$$= 1500 \text{ psi}$$

Motor displacement is calculated from Equation 28:

$$175 = \frac{216{,}000}{2\pi} D_{mm}\left[(1 - 0.05) - \frac{0.966 \times 10^{5}(10^{-8} + 10^{-8})}{(1 - 0.966)}\right]$$

$$D_{mm} = 0.0057 \text{ cu ft per revolution}$$

The required displacement for an ideal motor is:

$$T_m = \frac{\Delta p D_{mm}}{2\pi}$$

$$175 = \frac{216{,}000\, D_{mm}}{2\pi}$$

$$D_{mm} = 0.0051 \text{ cu ft per revolution}$$

The displacement required for any given speed, with a constant torque of 175 lb-ft can be calculated from Equation 29:

$$175 = (15)(2.088 \times 10^{-5})\left(\frac{3000}{60}\right)(57 \times 10^{-4}) \times \left[\frac{(1 - 0.05)(D_R - N_R)}{10^{-8} + 10^{-8}} - 10^{5} N_R\right]$$

$$N_R = 0.998 D_R - 0.0422$$

Similarly, for a constant torque of 100 lb-ft, $N_R = 0.99 D_R - 0.024$, and for a constant torque of 50 lb-ft, $N_R = 0.999 D_R - 0.012$.

For each value of D_R shown in Fig. 9, a corresponding value of N_R can be found for each of the above constant-torque values. Corresponding values of T_o/T_i can then be determined from Fig. 9. These values are shown in Fig. 18 as a function of N_o/N_i.

The performance characteristic at constant pressure can be calculated from Equation 32:

$$2000(144) = 2\pi(15)(2.088 \times 10^{-5}) \times \left(\frac{3000}{60}\right)\frac{D_R - N_R}{10^{-8} + 10^{-8}}$$

$$N_R = D - 0.0585$$

If $\Delta p = 5000$ psi, $N_R = D_R - 0.1462$. These data are shown in Fig. 19.

The effect of a sudden change in displacement can be calculated from Equations 29 and 32. Consider the transmission operating at $D_R = 0.1$ and optimum conditions. Then $N_R = 0.058$, $\Delta p = 1500$ psi, and $T_m = 175$ lb-ft. If D is suddenly increased to 0.5, from Equation 29, $T_m = 1820$ lb-ft. From Equation 32, $\Delta p = 15{,}000$ psi.

The efficiency $[(N_o/N_i)/T_o/T_i]$ will drop from approximately 27 per cent to 10 per cent.

Operation at 1500 psi gives the best efficiency, which increases as the speed ratio increases, Fig. 18. These data for this curve are obtained from the line of best efficiency shown in Fig. 9.

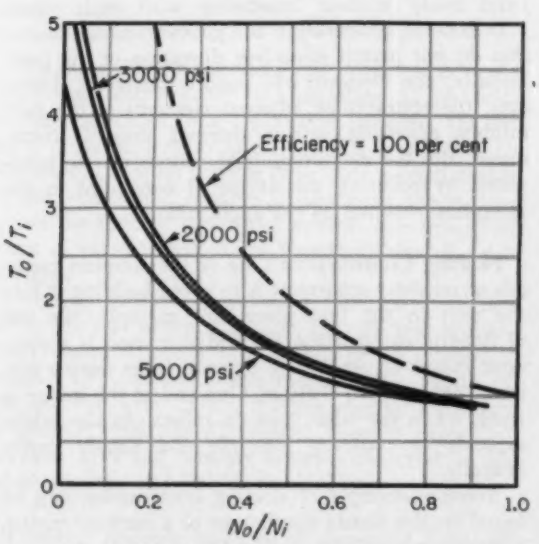


Fig. 19—Performance at constant pressure.

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A designer's guide to

THERMAL STRESSES

Part 3—External Factors in Design

- Constraint
- Temperature Gradient
- Expansion Compatibility

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CHOICE of design configuration is the most powerful tool available to the engineer designing for thermal stress. Often, however, the principles upon which the choice must be made are opposed to those for mechanical loading. Thus, making sections more bulky frequently reduces operating stresses in mechanical loading, but may do more harm than good in thermal loading. For this reason, it is important to understand the geometric and thermal factors over which the designer has some control.

Some of the methods used in reducing undesirable thermal stress concentrations are: 1. Reducing constraints. 2. Controlling the temperature. 3. Using materials with compatible expansion characteristics.

• Constraint

When the various elements of a structure are subjected to different temperatures, each part tends to expand a different amount. In some cases the tendency toward natural expansion coincides with the geometrical configuration, and the elements can expand freely without interfering with each other.

In general, temperature and geometrical configuration do not permit stress-free distortion of the part. Usually, the element will distort somewhat. However, the restraint by adjacent elements of the part inhibits distortion, and a thermal stress is introduced. But the magnitude of this stress can be minimized by reducing the degree of constraint to the minimum required by the application.

Floating Construction: One of the simplest methods of relieving constraint is to avoid building it into the part in the first place. For example, the use of floating construction for bridge trusses[1] is a common means of preventing thermal stress during seasonal temperature changes. One end of the bridge is fixed, while the other rests on rollers. As the bridge expands or contracts the free end simply moves laterally.

Another example of floating construction can be found in the nozzle diaphragm of a turbine engine,

[1]References are tabulated at end of article.

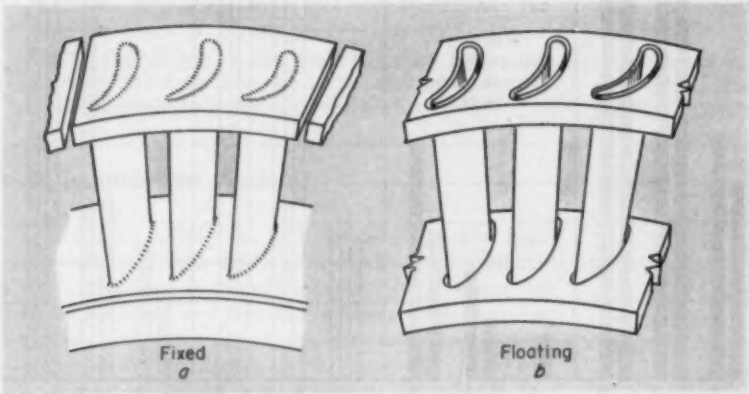

Fig. 9—One method of relieving constraint in gas-turbine nozzle diaphragms. Partial relief is obtained by segmenting the outer ring, *a*. A better method is to make the vanes free-floating in contoured slots, *b*.

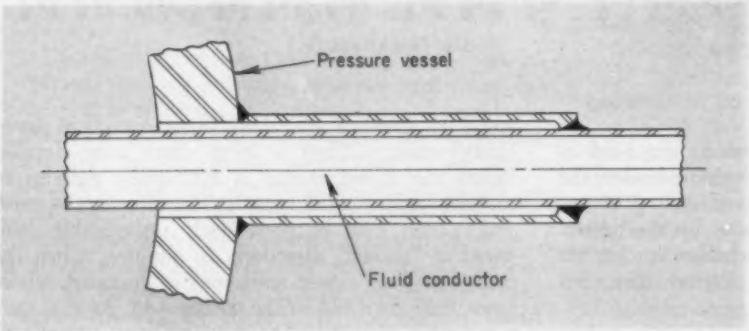

Fig. 10—Thermal sleeve, joining a pressure vessel to feed tube. This provides a large effective weld, avoids high thermal gradients that would otherwise be set up between the vessel and tube.

Fig. 9. Such construction relieves thermal stresses induced by unequal operating temperatures in the vanes.

Localized Flexibility: In some applications, leakproof connections must be maintained at the ends of pipes or other fluid-conducting passages, yet the ends must be free to allow thermal expansion. In this case, it is often possible to provide a small region of high flexibility, capable of absorbing the motion caused by thermal expansion. Bellows and expansion loops of various designs are frequently used for this purpose.

Another means of providing localized flexibility is the thermal sleeve, Fig. 10.[2] This method is especially useful where a tube is welded to a pressure vessel. The thermal sleeve increases the length of the effective weld. Thus, the temperature transition is gradual, and the differential thermal expansion between tube and pressure vessel is absorbed in the relatively long and flexible thermal sleeve.

Gaskets: Another method of absorbing localized strain is by means of gaskets. These are often used as spacers between blocks of concrete in roads and bridges. Another application where gaskets are especially useful is in pressure-vessel closures,[3] where the difference in cooling and heating rate between the vessel and the bolts can cause either undue stress or looseness between body and closure.

Contouring: Since thermal stresses are caused by constraint during thermal expansion, massive cores should be avoided where they might prevent the natural expansion of a less-massive heated region.

An interesting example is a locomotive wheel, Fig. 11. Such wheels not only carry the weight of the locomotive, but they also act as braking surfaces. The rims reach 1000 F before the temperature at the center of the wheel is appreciably raised. The problem is similar to that of the turbine wheel, in which free expansion of the hot rim is prevented by the cool massive central core. Compressive plastic flow occurs in the rim during heating, followed by residual tensile stress upon cooling. After repeated cycling, rim cracking occurs, which rapidly spreads

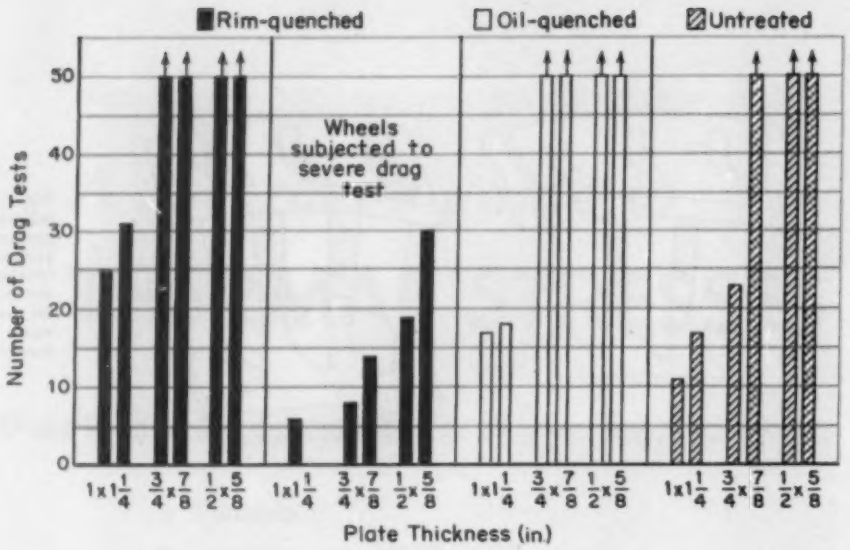

Fig. 11—Effect of size on cyclic life of locomotive wheels under thermal stress. Ordinate shows the number of drag tests before fracture. Under all test conditions, the thin web gave best thermal-fatigue results. Arrows indicate that wheels did not fracture.

and causes total wheel fracture.[3]

In turbine buckets, hollow sections are used to avoid massive cores. In a solid turbine bucket the surface, which is first to be heated during engine starts, is constrained from expansion by the central cores, which heat more slowly. A hollow bucket not only removes the constraining central core, but permits internal cooling.

Size Limitation: Large size is nothing more than the addition of constraint, since in a large body the portion undergoing rapid temperature change during thermal shock is generally prevented from expansion or contraction by a massive section which heats and cools more slowly. One way to minimize thermal-stress problems, particularly in thermal shock, is to keep the size of the structure to a minimum. Where the structure must be large, consideration should be given to a segmented construction, with each module small enough to have the necessary thermal-shock resistance.

Tests on hollow steatite discs have shown the importance of size in thermal-shock applications.[4] The discs were heated to a uniform temperature, and their surfaces rapidly cooled. Final results, Fig. 12, show that the smaller the body the more resistant it is to thermal shock. However, there is a limit in temperature difference ΔT during thermal cycling below which fracture will not occur regardless of how large the body is. This limit is numerically equal to the parameter $\sigma_s/E\alpha$.

One way to take advantage of the size effect is to build up a large structure from a number of small segments, Fig. 13. Such a structure can be regarded as precracked, requiring no additional cracking to relieve incompatibility under thermal expansion. In a sense, the structure is already cracked, but the cracks are located in a manner that can be tolerated during thermal operation.

In the continuous structure the cracks appear while the structure contains a large amount of stored elastic energy. Thus a large crack may develop before the stored energy is sufficiently reduced to prevent further crack growth. The direction of crack propagation may be particularly unfavorable compared to "chosen" directions. In addition, when the crack starts, an elastic wave may be initiated, whose stress field may add to the design load. As the crack propagates, the structure may collapse because of

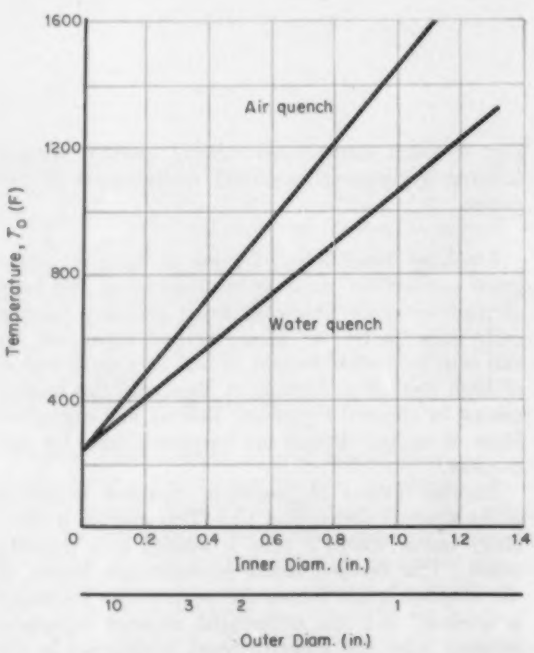

Fig. 12—Effect of size on steatite disc specimens in thermal shock. Intercept on vertical axis represents infinite size, and should be equal to parameter $\sigma_s/E\alpha$. Independently determined values give $\sigma_s/E\alpha = 100$ to 250 F.

lack of strength under mechanical and thermal loading.

In the segmented structure, on the other hand, the directions and sizes of cracks are controlled. No large amounts of elastic energy are suddenly released, and if one of the segments does crack, the interface between two segments acts to stop the crack, particularly if the metal is ductile.

• Temperature Gradient

In most applications, high temperatures and temperature gradients are present under service conditions. However, it often happens that unnecessarily high gradients are tolerated because of incomplete understanding of their origin, because of insufficient attention to the details of the operating variables, or because of failure to take advantage of simple devices for relieving at least part of the problem.

Operational Control: One solution to failures involving thermal distortion and thermal-stress fatigue is to minimize temperatures and temperature gradients by using more gradual and controlled starts. In any application where there is no urgent need for rapid starting, some technique should be used for limiting the rate of temperature build-up during the most critical portion of the cycle.

In one engine study,[5] made to determine the potential increase in life of turbine buckets under controlled-temperature starting, no failure was found after 900 starts, whereas 85 normal start-stop cycles were sufficient to cause cracking.

Auxiliary Heating or Cooling: In cases where the highest temperature gradients are developed during the transient period, it is sometimes possible to add auxiliary heat during this period to the regions that would otherwise remain cold, thereby reducing the gradients.

An example may be found in turbojet-engine discs. Such discs usually operate with a high temperature gradient between rim and center. The rim is hot because of its proximity to the hot gas impinging on the buckets, while the center must be kept cool because of the high centrifugal stress it must carry, and because of its proximity to bearings. Usually, the temperature differential is maintained by forced-air cooling of the central region. However, high gradients develop unintentionally during the transient period. The rim heats up rapidly, while the central region heats up rather slowly because of thermal inertia. Thus, the rim tends to expand much more than the center, but is prevented from expanding by the huskier center region.

Gradual starts probably would have relatively little beneficial effect on the significant thermal gradients in the discs because of their high thermal inertia. A more reasonable approach is to accept the fact that the rim will get hot rapidly, but, since the center must ultimately reach a temperature of 450 F (which is its safe design temperature), it might then be desirable to hasten achievement of this temperature, thereby reducing the temperature differentials.

Such an approach might maintain thermal stresses during the transient condition equal to, or lower than, those during the steady-state condition. In one illustrative computation, this procedure showed a thermal stress cycle life five times greater than that

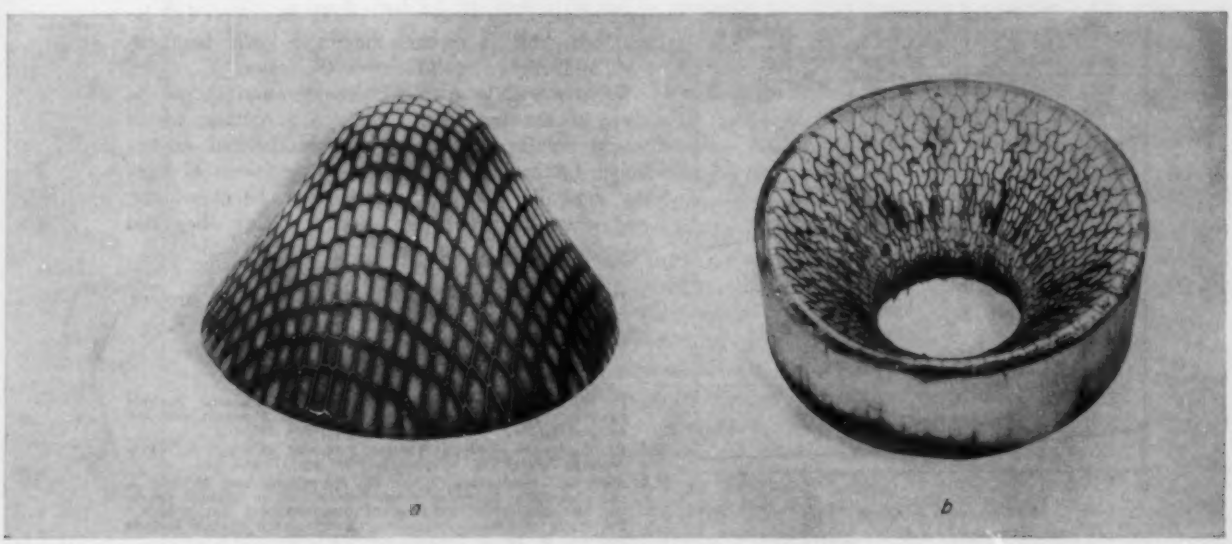

Fig. 13—Examples of segmented construction: *a*, honeycomb-reinforced nose-cone; *b*, honeycomb-reinforced ceramic rocket nozzle. The rocket nozzle, shown after being tested for 20 seconds in a hydrogen-oxygen motor at a stagnation temperature of 2900 K, showed excellent thermal-stress characteristics.

under normal conditions.

Insulation: Since temperature gradients depend on heat flow, greater retardation of heat will result in lower temperature differentials and, therefore, lower thermal stresses.

An example is given in Fig. 14, which shows a two-component assembly in which heat is retarded only by the two bars. This figure illustrates the care that must be taken in locating the insulation. If the insulation placed in region *A*, not only will $(T_1 - T_2)$ be decreased, but T_1 will also very likely be reduced. If the insulation is placed at region *B*, the heat flow will be reduced, but the temperature difference may not be reduced at all, since most of the temperature drop will be across the insulation. In addition T_1 will likely remain high. If the insulation is placed in region *C*, the temperature differential will be reduced, but both T_1 and T_2 will remain high. This shows that the best location for insulation is closest to the source of the heat, in this case region *A*.

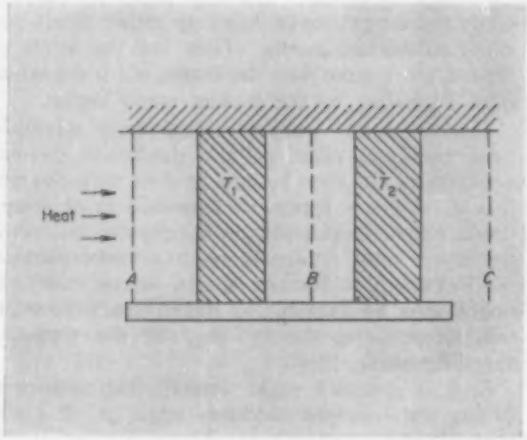

Fig. 14—Two-bar assembly, showing possible locations for thermal barrier. Best choice is at *A*, which is closest to the heat source.

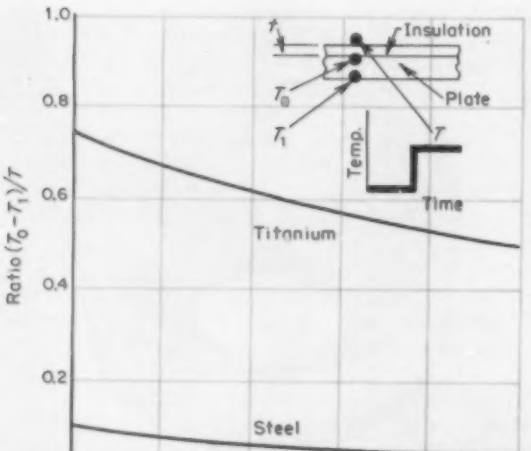

Fig. 15—Effect of surface insulation on temperature gradient across a plate during thermal shock. Ordinate shows the ratio of the temperature gradient across the plate to the step change in temperature causing the thermal shock.

Calculations on the effect of surface insulation have been made[1] for the simple case of 1-in. plates of titanium and of steel, Fig. 15. Of the two materials, steel benefits more from the insulation because of its higher conductivity. When the plate material has poor thermal conductivity, as in the case of titanium, the additional insulation value of the surface layer does not cause as high a percentage reduction in the heat flow, and a large part of the temperature drop still occurs in the plate.

• Expansion Compatibility

Thermal stresses arise because the elements of a structure are constrained from expanding according to their temperature and thermal-expansion characteristics. In some cases, temperature nonuniformities cannot be avoided, but compatibility of expansion can still be achieved if the expansion of one element does not interfere with the expansion of another element having a different temperature and different coefficient of expansion. Thus if the element having the higher temperature has a lower coefficient of expansion, the total expansion can be matched with an element having a lower temperature and higher coefficient of expansion.

Wherever it is practical, consideration should be given to the use of bimetallic construction, which would result in more compatible thermal expansions. Other factors, such as the problems of joining dissimilar metals may, however, be overriding, and must be taken into account before the final selection of materials can be made.

Part 4 of this series will discuss residual stresses, strain concentrations, and surface protection.

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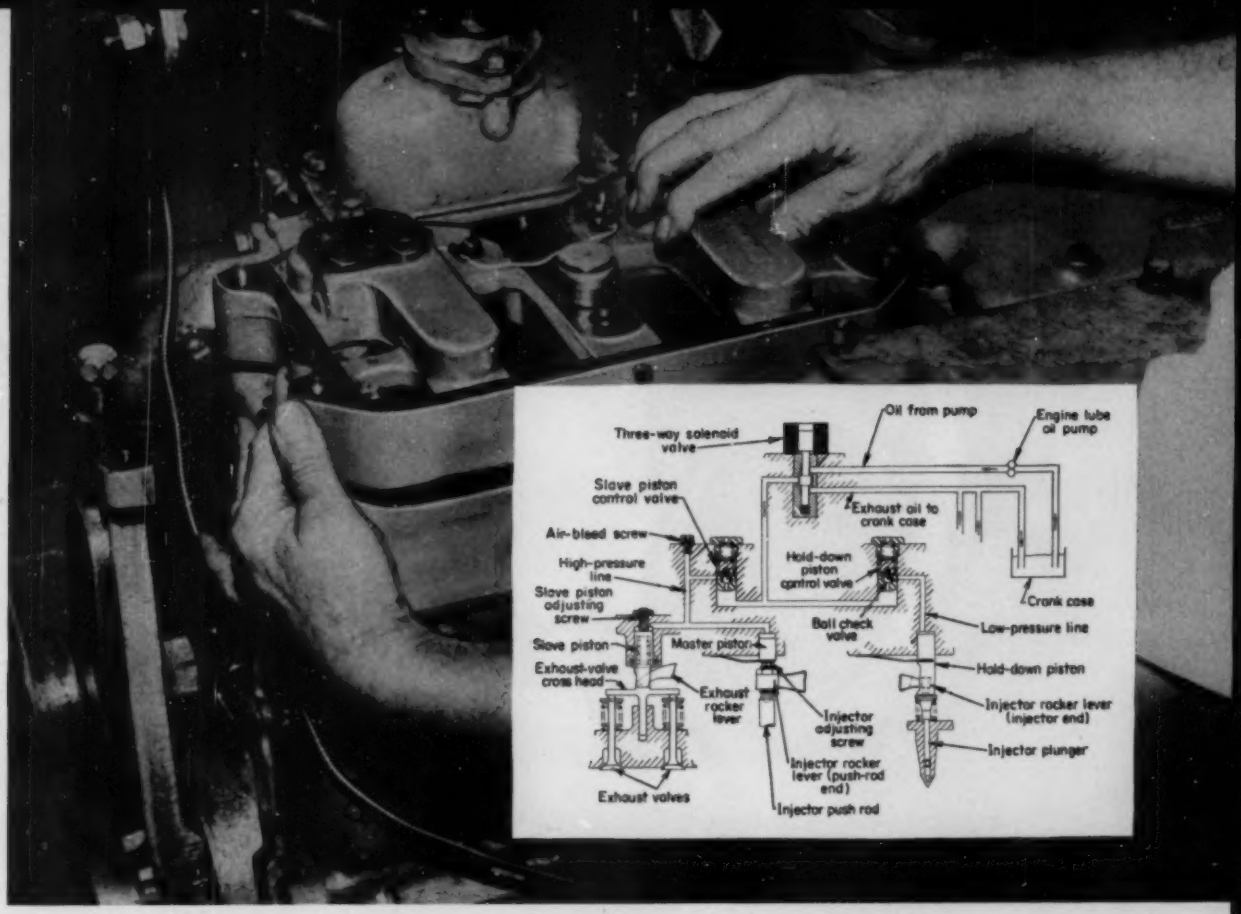
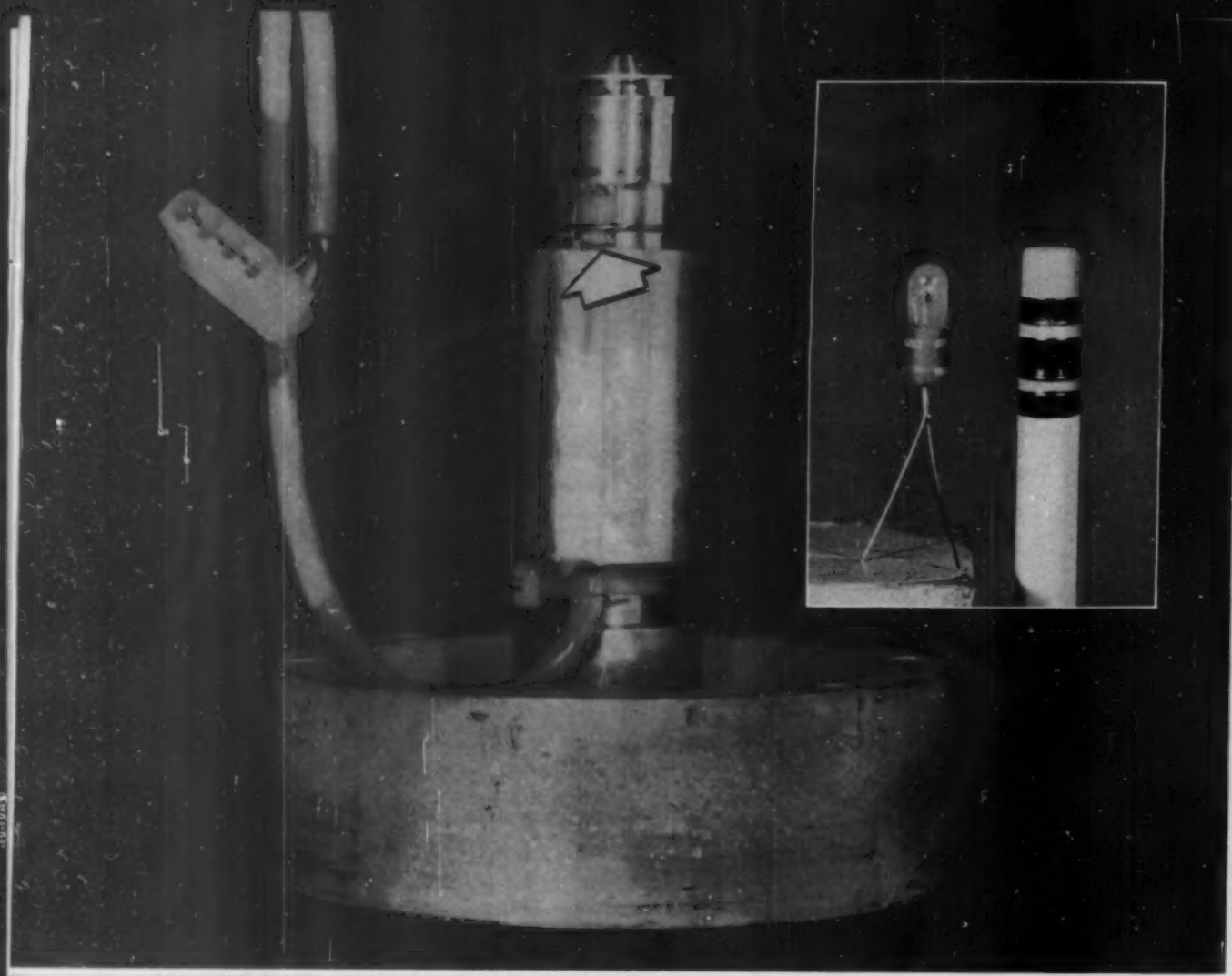
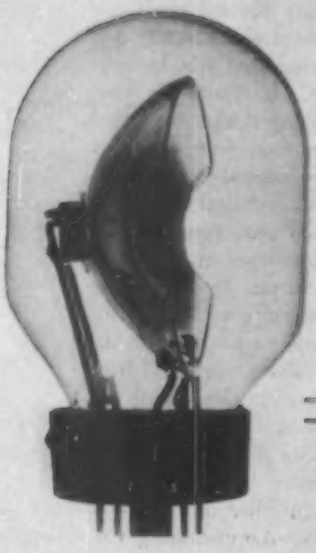
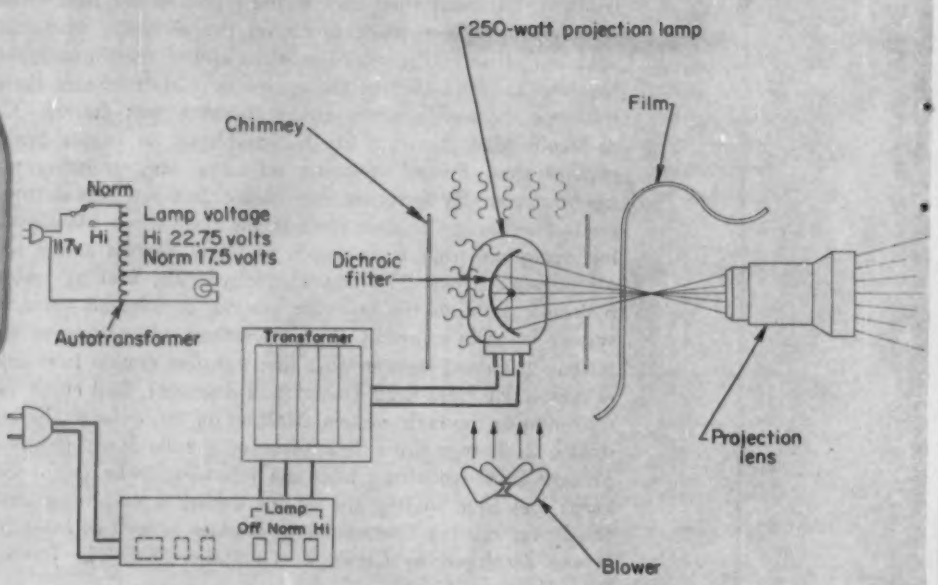


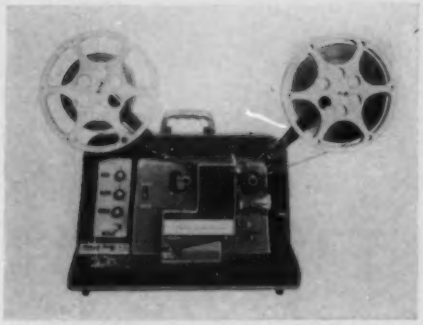
Diesel Engine Brake

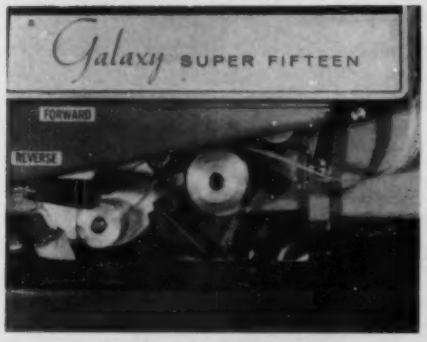
Auto drivers who know about using engine drag to brake vehicles on steep hills may be surprised to know that diesel engines have very little inherent braking ability. The spark ignition engine drags because it is drawing a vacuum against a closed throttle. The diesel is not equipped with a throttle as such. Speed is controlled by metering fuel, but air is allowed to flow as freely and efficiently as possible. When a diesel-equipped vehicle pushes its engine with fuel valve closed, energy used by the piston on the compression stroke to compress a column of air is almost all transmitted back to the piston on the next stroke as the air expands. Attempts have been made to correct this difficulty by having the exhaust valve open out of normal sequence near the end of the compression stroke. Usually this involved an extra cam in the engine or a shift in cam timing that was brought into operation only when engine braking was desired. C. L. Cummins Div. of Jacobs Manufacturing Co. has developed an engine braking design for diesel engines that, instead of using an extra cam, transfers motion from the fuel injection cam. By fortunate coincidence, fuel injection during normal powered operation occurs at the same place in the cycle where blowdown is desirable in braking operation—that is, from ten to thirty degrees before top dead center of the compression stroke. The new electrohydraulic braking system uses engine oil as hydraulic fluid to transmit the motion. A solenoid valve directs the oil to the system when it's needed. Two operations are performed simultaneously by the system: 1. Closed high-pressure line transfers motion from injector push rod to the exhaust-valve cross head (left side of diagram). Ball check valve prevents oil from returning to the main system. Makeup oil can enter at the bottom of the push-rod stroke. 2. Low-pressure line operates a hold-down piston to keep the injector plunger from recovering after the injection stroke (right side of diagram). This keeps fuel from fouling the engine during a non-firing stroke. The unit can be fitted over existing Cummins-type engines as well as being installed on new ones. It was developed by Clessie L. Cummins Div., The Jacobs Manufacturing Co., West Hartford, Conn.

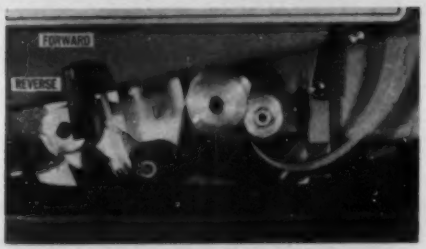


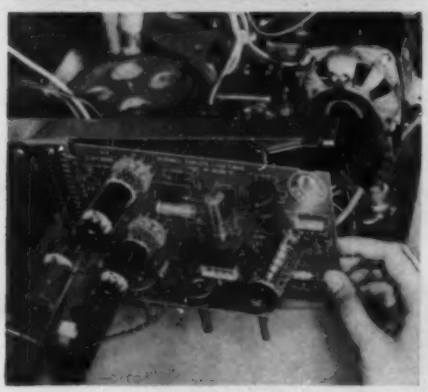



250-watt projection lamp
Film
Chimney
Norm
Lamp voltage
Hi 22.75 volts
Norm 17.5 volts
117v
Hi
Dichroic filter
Autotransformer
Transformer
Projection lens
Lamp
Off Norm Hi
Blower







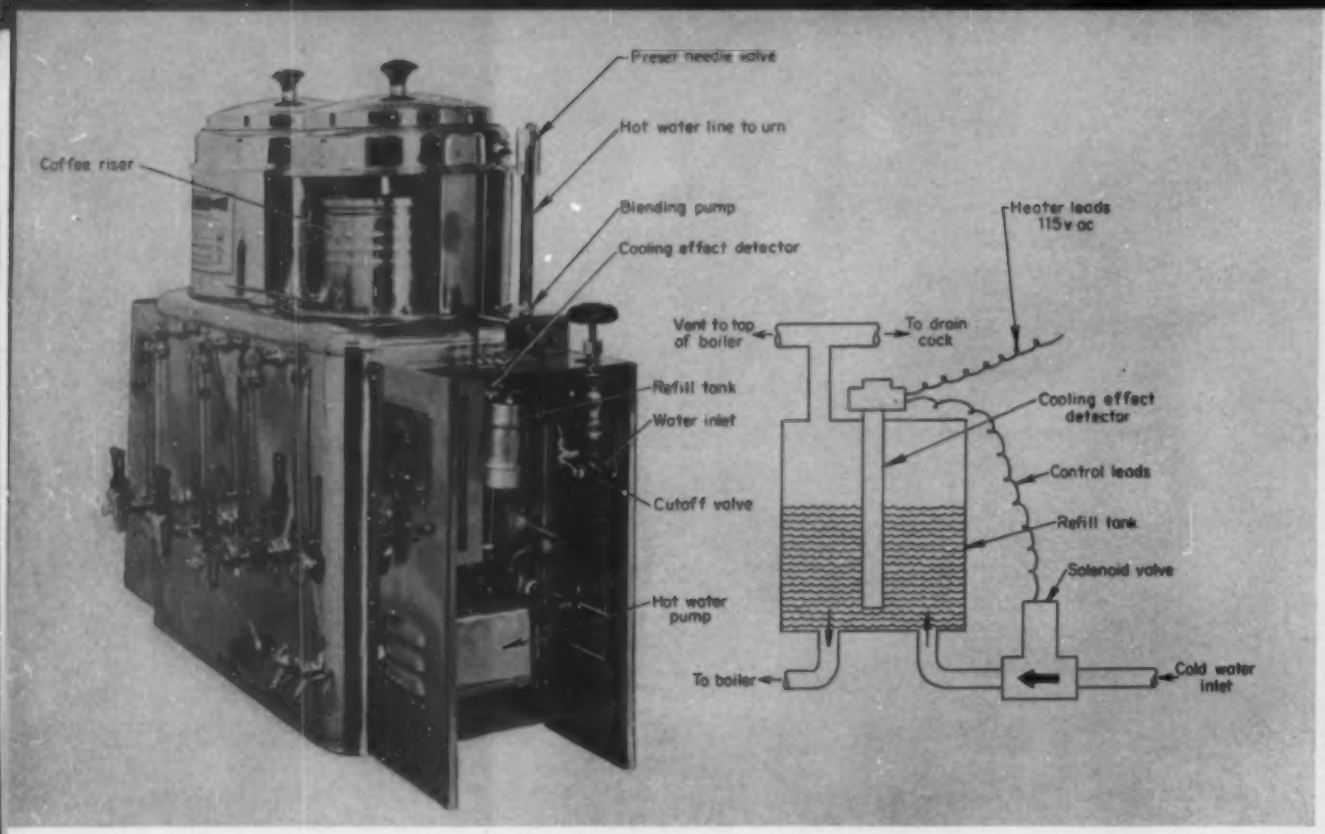


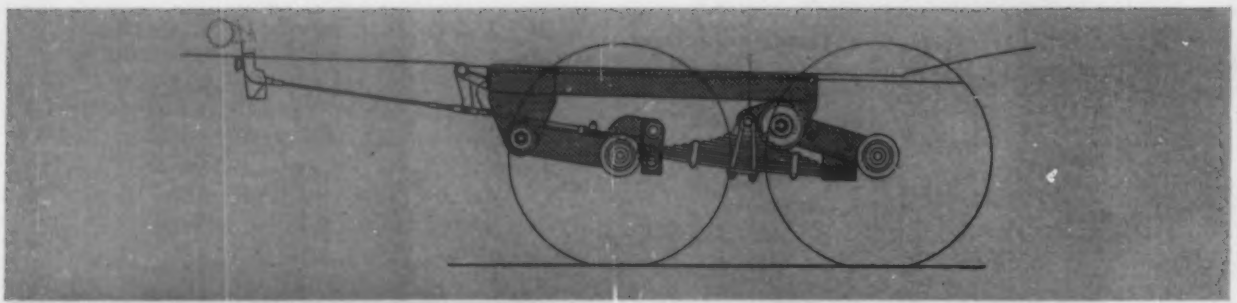
Cool Projector

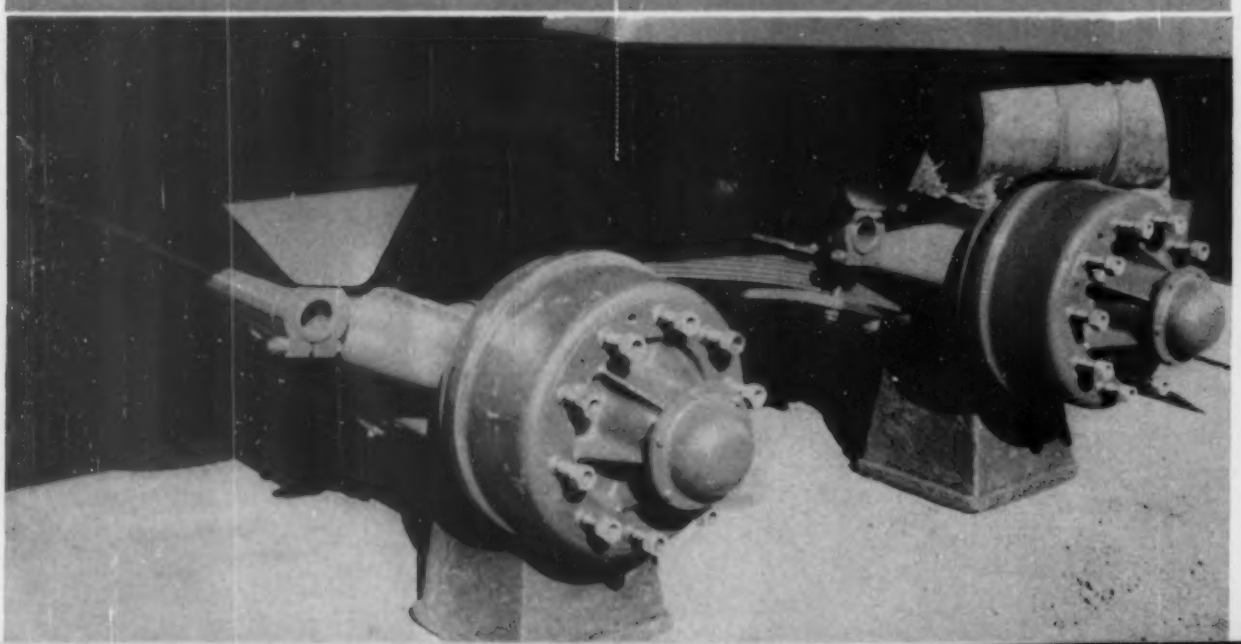
Graflex has designed a new 16-mm sound projector around a low-voltage, high-current lamp that makes 250 watts do the work of 800. A two-position autotransformer furnishes low-voltage current for the projector. On high, output voltage is 22.75 v, producing light from the 250-w lamp equivalent to that from a conventional 1200-w lamp. Lamp life on the bright setting is 10 to 14 hrs. On low, the normal setting output voltage from the transformer is 17.5, producing light equivalent to that from a standard 800-w lamp. Lamp life is 150 hours. Reflector built into the lamp has dichroic coating to transmit infrared rays and reflect usable light. Elimination of infrared filter and condenser lenses simplifies the new projector's optical system.

• Photo transistor of a new type eliminates some amplifier stages needed in conventional sound pickups. Besides producing a stronger signal, it avoids the microphonic tendencies of other cells. The tiny cell is mounted in the sound head, eliminating mirrors and light pipes.

• Borrowing an idea from tape-recorder design, the projector uses a drop-in slot to simplify film threading through the sound head. Flipped to "Thread," the direction lever clears the slot for threading. Flipped "Forward," it closes the sound head. Lexan gears have more dimensional stability than nylon, says Graflex. Lamp for the projector was developed for Graflex by Sylvania.


Preset needle valve
Hot water line to urn
Coffee riser
Blending pump
Cooling effect detector
Heater leads 115v ac
Vent to top of boiler
To drain cock
Refill tank
Water inlet
Cutoff valve
Hot water pump
Cooling effect detector
Control leads
Refill tank
Solenoid valve
To boiler
Cold water inlet





Bi-metal Liquid-Level Detector

Thermostatic switch, replacing float controls, senses water level in a supply boiler for a coffee urn and operates a control valve to keep it at optimum level. Heating element in the unit maintains design volume of water at coffee brewing temperature. When the water drops below a certain level, temperature of the exposed heater-thermostat rises above set-point, and the switch opens the water supply valve. As cold water flows into the tank, the thermostat cools and closes the supply valve. Conventional float type and probe type liquid level gages were tried, but the float types tended to stick, and the probe types lost their sensitivity as they collected a coating of mineral deposits. Control is used in a coffee maker developed by Cecilware-Commodore Co., Long Island City, N. Y. The cooling-effect detector is manufactured by Fenwal Inc., Ashland, Mass.

Trailing-Arm Suspension

Only vertical loads are felt by springs in the wheel suspension of a new semi. Trailing radius arms drag wheels easily over obstacles without stubbing. One multileaf spring per side absorbs road shocks from both forward and rear axles. Rear radius arms are continued forward of the pivots and clamped to the spring to form the reaction bearing for the spring. Loads on either axle are transmitted by lever action to the other axle. This helps keep wheel loading uniform and adds to the vehicle's road stability. Radius-arm bearings are Ferrobestos bushings and thrust washers which need no lubrication. They are claimed to add considerable damping to radius-arm oscillations. Trailing-arm suspension was developed by Cranes Ltd., Dereham, U. K.

Accentuate the POSITIVE in ENGINEERING RELATIONSHIPS

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EVERY engineering problem and every personal relationship has both positive and negative elements. Reactions of people to what we say or write depend on which of these elements is emphasized.

The engineer may recognize that what he is about to convey is either favorable or unfavorable to the person who receives the information. And he may feel that the situation warrants using direct, blunt language. However, putting unpleasant situations in negative terms often erects a barrier between the two parties. It isn't necessary to have a "happy-happy" attitude in the face of all circumstances, but it is necessary to find the positive elements and build upon them to be effective in reaching the real engineering goals.

Suppose, for instance, that an engineer is preparing a report to a customer on engineering tests. One way of summarizing the facts might be:

> "Eighty per cent of the rods subjected to thermal cycling tests failed. The cause of failure of this high percentage of samples has not been determined. Failure of one of the rods resulted in damage to the test rig which will delay further tests for one week."

After reading this nugget, the customer probably questions his wisdom in hiring the engineer or the firm for the work. The same facts, written with a positive approach, could be reported as:

> "Twenty per cent of the rods subjected to thermal cycling tests passed. Work has been started to analyze the characteristics of these rods. Minor damage to the test rig was sustained when a defective rod failed. The rig is being repaired, and tests will continue within a week."

In another case, suppose that the engineering firm informs the customer of the status of a job in progress by regular reports. The customer has reviewed one of the designs and suggested that a change be made in a structure. The engineer might reply,

> "We have reviewed your analysis of our structure and found several errors in method which we believe invalidate your recommendation that we add additional support members. Unless we are notified to the contrary, we will proceed on the basis of our original design."

Or he might write:

> "We have studied your analysis of our structure very carefully and have compared it with our own. Our equations appear to diverge from yours at steps 3 and 7. Since your costs for this job will be appreciably less if no additional support members are required, we ask that you compare and re-evaluate the enclosed analyses and comments. Meanwhile, we are proceeding on the basis of the original design in the interests of time."

Positive expression does not imply lack of sincerity or truth. It is simply a way of expression which increases the forward movement of events rather than congealing a faulty situation or outlining an unpleasant situation with nonconstructive comments.

Circle 25-6 on Page 19 for extra copy.

INDICATORS RECORDERS and CONTROLLERS

basic electronic controls 2

JACOB H. RUITER, JR.
Weston Instruments Div.
Daystrom Inc.
Newark, N. J.

and

R. GORDON MURPHY
Wallace & Tiernan Inc.
Belleville, N. J.

Fundamentally, electronic controls consist of transducers for sensing variables and actuators for making changes. But more than these two elements are involved. Indicators and recorders give evidence of how a system is functioning. Controllers govern the operation of the actuators.

Indicators visually display operating characteristics as they happen. As a result, on-the-spot decisions are possible, and immediate changes can be made to maintain preset functions.

Recorders provide permanent records of operating characteristics which change rapidly or require careful study. Often, indicators and recorders are combined into one unit.

Controllers receive transducer signals, compare, analyze, and amplify them, and produce output signals for the actuators. Controllers thus automatically control a system by effecting the necessary changes in the proper amount and at the proper time.

This is the second and concluding article on electronic controls. The first article appeared in the November 23 issue of *Machine Design*. Both articles are based on chapters from a new book, *Basic Industrial Electronic Controls*, to be published in January, 1962, by Holt, Rinehart and Winston Inc.

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INDICATORS

Indicators are a part of everyone's daily activity. A few examples are thermometers of all kinds, pressure gages, barometers, electric meters, and fuel-level indicators.

Indicators are installed when no permanent record is required of the operation, or when variations are slow enough or far enough apart to permit periodic manual records to be prepared. An altimeter for indicating elevation above sea level can be used in topographic surveying. In such a case the indicated changes are slow, and the differences in elevation at multiple points are recorded for future use in preparing a typographic map.

Indicators can be made with stationary scales and moving pointers or with moving scales and fixed reference points, Fig. 1. Accuracy of indicators or the reading of indicators can be improved by calibrating the scale in smaller increments. Often, a mirror is incorporated on the scale to permit correction for parallax. When the pointer and the image of the pointer in the mirror are superimposed, an error in reading is eliminated, Fig. 2.

The means used to move an indicator pointer or scale are the same means used to position or move the pen of a recorder.

INDICATOR MOVEMENTS

The three basic types of movements used for indicating electric current or voltage are: 1. Permanent-magnet moving-coil movement, often called the D'Arsonval movement. 2. Iron-vane movement. 3. Electrodynamic movement, often called the dynamometer movement. Of these three, the permanent-magnet moving-coil movement is the most common.

Permanent-Magnet, Moving-Coil Movement: The

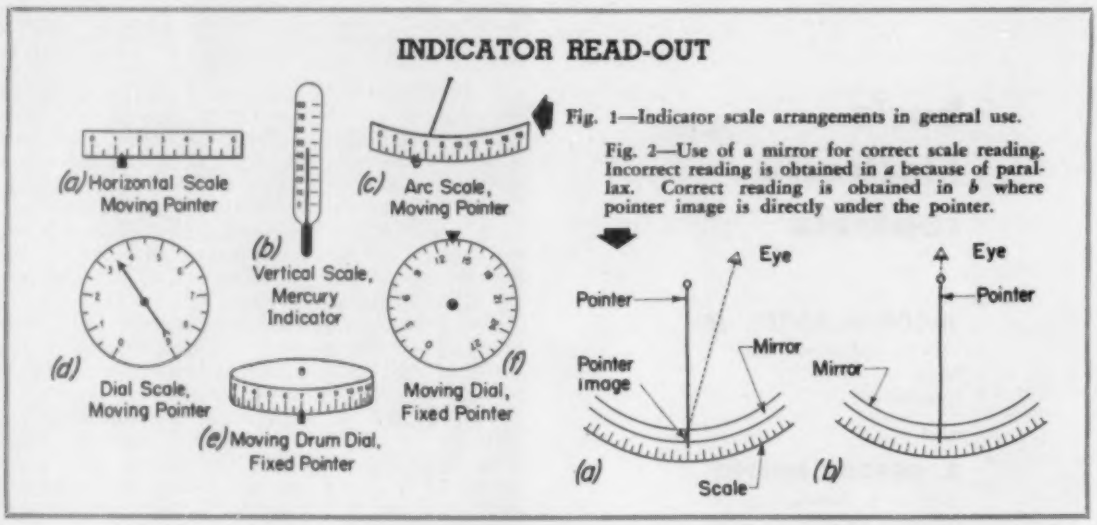


Fig. 1—Indicator scale arrangements in general use.

Fig. 2—Use of a mirror for correct scale reading. Incorrect reading is obtained in *a* because of parallax. Correct reading is obtained in *b* where pointer image is directly under the pointer.

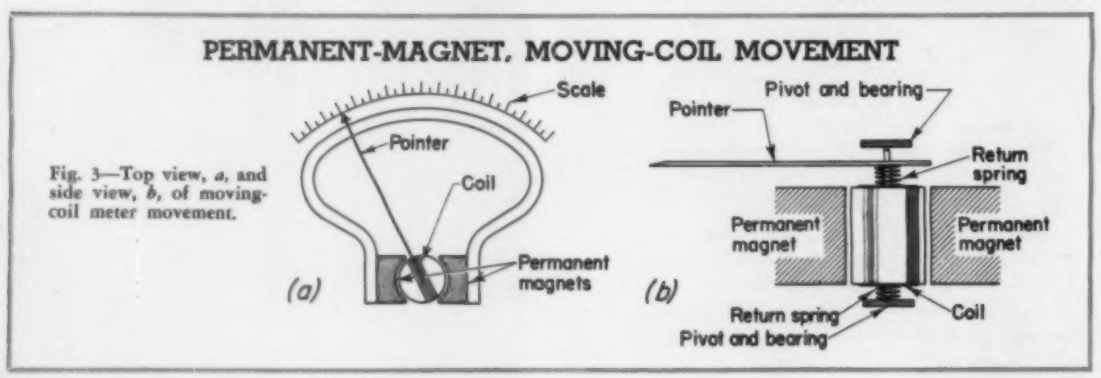


Fig. 3—Top view, *a*, and side view, *b*, of moving-coil meter movement.

MOVING-IRON-VANE MECHANISM

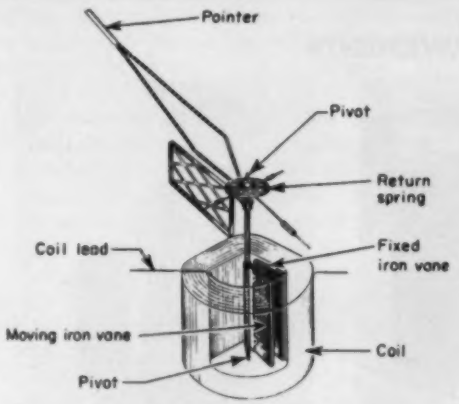


Fig. 4—Iron-vane meter movement for measuring alternating current.

ELECTRODYNAMIC MOVEMENT

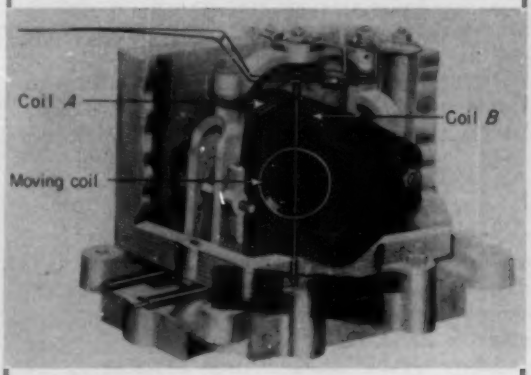


Fig. 5 — Electrodynamic movement in which two coils create the external magnetic field for the moving coil.

D'Arsonval movement is sensitive, relatively rugged, and readily adapted for indicating either voltage or current. It is designed for measuring direct current and dc voltage, but it may be used on alternating current if the current to the meter is first rectified.

The moving coil, Fig. 3, is wound on a small coil form that is mounted on pivots and is free to rotate. The pointer, or indicating needle, is firmly attached to the coil form. Each end of the wire that is wound on the coil form is attached to a helically shaped metal spring—one spring at each end of the coil. The outermost ends of the helical springs are permanently fixed so that, as a force is exerted to turn the coil, tension is applied to the springs. The pointer indicates the strength of the force on the scale. When the force is removed, the springs return the coil to its orginal position, and the pointer points to zero.

The force that turns the coil is produced by current passing through the coil. The coil thus becomes an electromagnet. The north pole of the coil is initially located closest to the north pole of the permanent magnet. Since like poles repel, the moving coil rotates in a clockwise direction. Because the strength of the field in the coil is directly proportional to the current flowing through the coil, the moving-coil movement is essentially a current-indicating device.

Moving-Iron-Vane Mechanism: The iron-vane movement operates directly on alternating current without any need for rectifiers. The movement uses a fixed iron vane and a movable iron vane, Fig. 4. The movable vane is mounted on pivots. As the current to be measured flows through the coil, both iron vanes are magnetized with the same polarity. The repulsive force existing between the two iron vanes causes the moving vane to rotate away from the fixed vane. The pointer, attached to the movable vane, indicates the rotational force produced by and proportional to the current in the coil.

Electrodynamic Movement: The electrodynamic meter movement, Fig. 5, is basically the same as the permanent-magnet moving-coil movement except that the permanent magnet is replaced by two coils of wire. Field winding *A*, the moving coil, and field winding *B* are connected in series. As current passes through this circuit, the field coils and the moving coil become electromagnets. The moving coil turns on its axis. The pointer attached to the moving coil indicates on a scale the magnitude of the current. Since the magnetic field strength is directly proportional to current, the scale is linear.

The most distinctive advantage of the electrodynamic movement is that it can be made highly accurate. Also, because of its design, it responds directly to either alternating or direct current.

RECORDERS

In many types of control, an indicator is not sufficient. Often, system variations are too rapid to read and record. In such cases, a recorder must be used to provide a permanent record of change. This record can be studied at a future time, and corrections can be made for future operations.

The choice of a recorder depends upon desired accuracy, speed of response, availability of recorded

GALVANOMETER MOVEMENTS

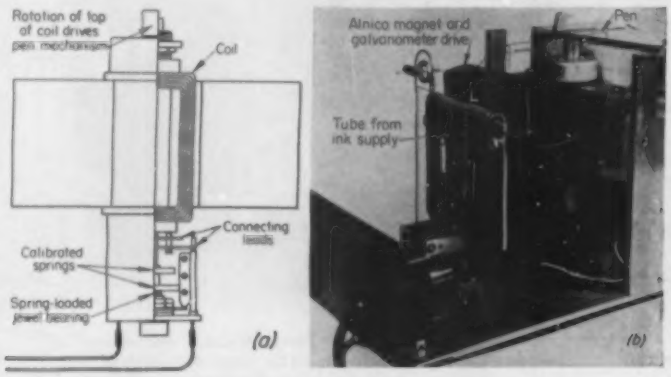


Fig. 6—Galvanometer movement for measuring amplitude variations of dc signals in cutaway view, *a*, and installed in a recorder, *b*. (Courtesy, Texas Instruments Inc.)

Fig. 8—Adjustment of magnet assembly which contains several galvanometers. (Courtesy, Minneapolis-Honeywell Regulator Co., Heiland Div.)

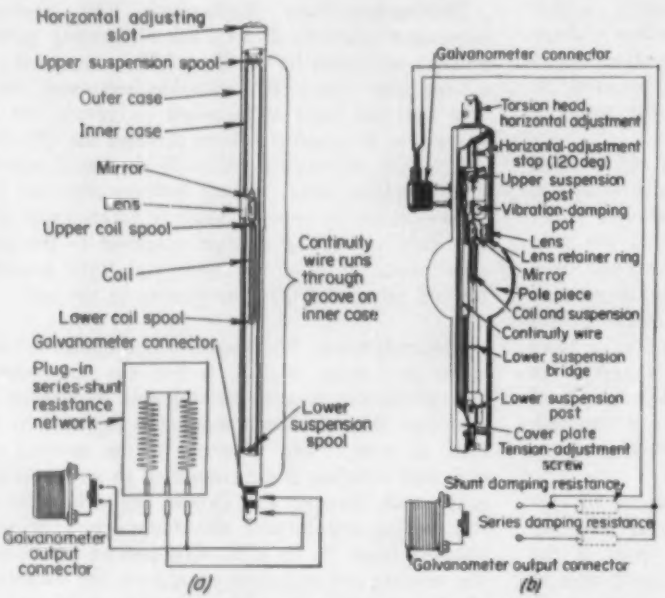


Fig. 7—Damped electromagnetic galvanometers. The subminiature type in a double-sealed tube, *a*, responds to direct current and frequencies up to a maximum of 4800 cps. The solid-frame type, *b*, responds to direct current and frequencies up to a maximum of 2000 cps. (Courtesy, Minneapolis-Honeywell Regulator Co., Heiland Div.)

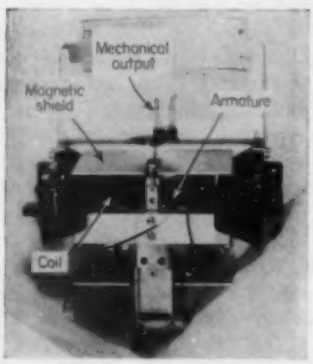


Fig. 9 — Electrodynamometer mechanism for measuring amplitude of alternating current or voltage. (Courtesy, General Electric Co.)

data, visibility of data, and method of signal input. All recorders consist basically of: 1. A measuring circuit—a means of receiving an input signal, using the signal directly, or amplifying it. 2. A recording device—a mechanism to receive the adjusted signal and actuate a pen, stylus, counter, magnetic head, or tape perforator. 3. A recording medium—a means of recording the data, such as a strip or circular chart or a magnetic drum or tape. 4. A chart drive—a mechanism for advancing or rotating the chart, drum, or tape, generally operated as a function of time.

MEASURING CIRCUITS

The most common means of measuring or detecting signals is by a moving coil or galvanometer movement, slide-wire potentiometer, bridge circuit,

differential transformer, or oscillator and beam balance. The type of measuring circuit to be used depends on the type and characteristics of the signal. The signal can be alternating current or voltage; direct current or voltage; or a change in resistance, frequency, or wave shape.

Galvanometer Movements: The permanent-magnet moving-coil and electrodynamic movements are also called galvanometer movements. They are used to record only the amplitude or the variations in amplitude of current or voltage. If the wave shape or wave form of each cycle of the ac signal must be recorded for examination, a rectifier cannot be used in the line. Thus, if the frequency of the signal to be measured is greater than 1 cps, the mass of the common moving-coil movement prevents it from responding to ac signals or from giving a true picture of changes in dc signals occurring at a rate greater than 1 cps.

Special galvanometer movements that show the wave form of signals having a frequency response up to about 5 kcps are available. A typical moving-coil movement for measuring variations in amplitude of dc or rectified ac signals is shown in Fig. 6. Rotation of the shaft of the moving coil drives the pen mechanism in proportion to moving-coil displacement.

When the signal frequency to be recorded is in the range of 100 to 4000 cps, the galvanometer must be extremely light and sensitive. Miniature galvanometers can also be used for dc and low-frequency measurements and can often be used in recorders to measure weak input signals directly without amplification.

With high frequencies, direct recording on a chart with inks or scribing mechanisms is impractical because of drag and inertia in the measuring circuit and recording mechanism. With a miniature galvanometer movement, the pen or stylus might well comprise a greater mass than the movement itself. To overcome mass and inertia, the miniature galvanometer is equipped with a mirror which reflects a light beam to a photosensitive chart. This system eliminates any mechanical linkage between measuring circuit and recording device.

When light-beam galvanometers of the types shown in Fig. 7*a* and *b* are used in recorders, the movement of the coil must be damped to prevent overshooting. Damping is a built-in characteristic which prevents the inertia of the moving coil from carrying it beyond the actual peak of the voltage being detected. Damping may be accomplished by electrical, electromagnetic, or by fluid means.

The two units shown in Fig. 7 are electromagnetically damped through the use of external shunt or series resistors to make the electrical resistance of the galvanometer equal the resistance of the source. Miniature light-beam galvanometers are also made with fluid damping, generally when the natural frequency is over 500 cps. The coil and lower suspension are immersed in a fluid to damp the oscillation. Proper damping reduces overshoot to a minimum and provides the best frequency response. Overdamping does not give a true record of the signal frequency, and underdamping allows overshoot so that the recorder produces false records.

Many recorders are made with several galvanometers. Each channel contains a galvanometer so that several related signals can be recorded on a single chart. The various functions are all measured at the same time, and the complete chart can be studied for relation of each function to the other. In some recorders all the galvanometers are installed in a single magnet assembly, Fig. 8. Direct-writing recorders using galvanometers can have up to 12 channels. Recorders using light-beam galvanometers are available with up to 60 channels.

To measure amplitude of ac voltage or alternating current directly, an electrodynamometer mechanism can be used, Fig. 9. The movement performs the same basic function as a D'Arsonval galvanometer—it converts ac signals to a rotation of the output shaft, which positions the pen mechanism.

Slide-Wire Potentiometers: Potentiometric measuring circuits are based on a system of null balance, whether it be voltage balance or current balance. Null balance is the point at which, when comparing an unknown quantity against a known value, no current flows in the circuit. Adjustment of the known value is achieved by using the voltage difference between the known and unknown values to drive a positioning motor.

In the circuit of Fig. 10, the slide-wire carries a fixed dc voltage so connected to the primary of the transformer as to oppose the unknown voltage. The sliding arm or contact permits picking off a known value of the fixed voltage. The unknown voltage from a transducer is fed to a converter where, by means of a vibrator, the direct current is "chopped" into alternating pulses which energize the primary winding of a transformer. The chopper converter in Fig. 11 could be substituted for the vibrator in Fig. 10.

The current in the secondary of the transformer in Fig. 10 is amplified and fed to one winding of a servomotor. A second motor winding carries alternating current of fixed phase. When current flows from the amplifier, the motor turns and, by mechanical linkage, moves the contact arm on the slide-wire toward a position of null balance. At this point the selected portion of known voltage from the potentiometer balances the unknown voltage, and no current flows in the transformer or servomotor. The shaft used to position the potentiometer arm is also used to drive the pen of the recorder.

The servomotor, with a fixed phase on one winding, rotates in either direction depending on the phase in the second winding. If the unknown voltage is greater than the known voltage, the chopped signal will cause the servomotor to turn in such a direction as to increase the known voltage selected by the contact arm. If the unknown voltage is less than the known voltage from the slide-wire, the alternating current from the transformer will shift phase 180 deg and drive the servomotor and contact arm in the opposite direction to pick off a lower known voltage.

SLIDE-WIRE POTENTIOMETERS

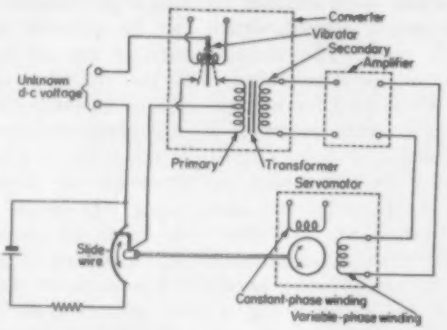


Fig. 10—Potentiometric measuring circuit for recorders and indicators.

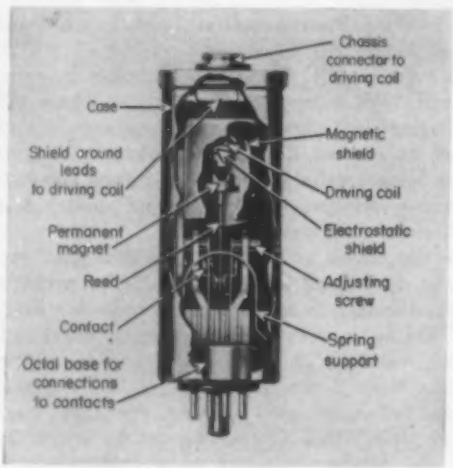


Fig. 11—Chopper converter with a single reed that is driven by 60-cps line current. The vibrating reed makes and breaks contact in a dc circuit, chopping the direct current into a series of pulses. (Courtesy, Leeds & Northrup Co.)

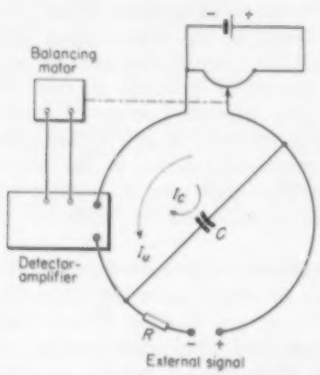


Fig. 12 — Resistance-capacitance damping circuit for potentiometric recorders and indicators. The detector, or unknown, current results from an unbalance between known (slide-wire) and unknown voltages. Damping current is produced by the rate of change of slide-wire voltage. (Courtesy, Leeds & Northrup Co.)

As the contact arm is driven across the slide-wire, the "error" voltage or difference, which is driving the motor, gradually diminishes until the balance point is reached. However, because of inertia in the system, the motor may cause the contact arm to move beyond the balance point. An error voltage, then, which is of reversed phase or polarity, will drive the motor in the opposite direction to return it to the balance point it has just overshot.

To prevent overshooting, the circuit is damped. One means of damping a circuit is the resistance-capacitance network shown in Fig. 12. Assume that unbalance exists and that the unknown voltage is greater than the slide-wire voltage. This causes current I_u to flow through the detector, and the balancing motor repositions the contact arm to increase the slide-wire (known) voltage. The full value of the unknown voltage does not immediately appear across capacitor C. Instead, C begins to charge up to the voltage corresponding to the new value of voltage across the slide-wire.

The charging current of the capacitor, I_c, is proportional to the speed of the slide-wire contact and the balancing motor. It opposes current I_u. With the motor at full speed, the error voltage reduces until I_u and I_c are equal and motor torque is zero. Further decrease in the error voltage causes I_c to exceed I_u, tending to reverse the motor and exert a braking torque. The unknown current and current charging the capacitor reduce toward zero, and the slide-wire contact approaches null balance. The resistance and capacitance components of the circuit are chosen to permit rapid recorder response without overshoot.

Potentiometer recorders are generally used when the input signal is direct current or dc voltage.

Bridges: When an input signal results from measurement of the resistance change of a transducer, a resistance bridge-circuit recorder is used. The bridge circuit operates on a null-balance principle and includes a slide-wire as part of the bridge, an amplifier, and a two-winding servomotor, Fig. 13. The sensing element, a resistance thermometer, for example, is another leg of the bridge.

The bridge is energized by a 120-v ac source through a transformer. As the condition of the sensing element changes, varying the signal, the bridge becomes unbalanced. The error signal is amplified and fed to one winding of the servomotor which rotates and moves the contact arm on the slide-wire to rebalance the bridge. The amplifier and servomotor are similar to the units used in the potentiometric circuit. The amplified error signal may cause the motor to rotate either clockwise or counterclockwise, depending on whether the resistance of the sensing element is increasing or decreasing.

Another type of bridge circuit, Fig. 14, consists of a fixed resistor, a resistance sensing element, and an adjustable capacitor for balancing the bridge. The balancing capacitor has two sets of stator plates and a single set of rotor plates. When the fixed resistance has the same value as the resistance of the resistance bulb, the rotor plates of the balanc-

ing capacitor rest with half of the rotor meshed with one set of stator plates and the other half meshed with the second set of stator plates. Thus, the impedances of both sets of balancing-capacitor stator plates are equal.

The bridge is energized with a low-voltage ac at 1000 cps. As the resistance of the sensing element changes, the voltage drop changes across connections 1 and 4 and, therefore, across points 1 and 3. By adjustment of the movable plates of the capacitor, the voltage drop in both bridge legs between points 1 and 3 can again be made equal. This is null balance. The unbalance detector circuit determines the amount of unbalance by comparing the error signal to a reference voltage, and then drives the Dynapoise motor to position the capacitor rotor so that the error voltage is reduced to zero.

Several other circuits based on this type of capacitance bridge are for use with strain gages, pressure cells, and conductivity cells. They are all based on the null-balance principle and include a drive unit for repositioning the movable portion of an adjustable capacitor to balance the electrical system.

Differential Transformers: Use of a differential transformer in a measuring circuit is shown in Fig. 15. The differential transformer is powered by a 115-v 60-cps current through the same cable energizing a flow transmitter. Using the same cable and power source eliminates frequent recalibration of the instrument since both transmitter and recorder-drive voltages change simultaneously.

The differential transformer is connected in series opposition with the transmitter. The voltage output of the differential transformer is varied by positioning a copper ring in the coils. The ring is mechanically linked to a drive motor. When transformer balancing voltage E_B and transmitter voltage E_G are equal and opposite, there is no voltage between points 1 and 2, and null balance exists. When the transmitter voltage increases or decreases as the result of a change in flow in the pipe, a voltage appears between points 1 and 2. This change in signal is amplified and fed to the unbalance detector where the phase relation of E_G to E_B is determined. The output of the detector is two dc voltages. The voltages differ in magnitude

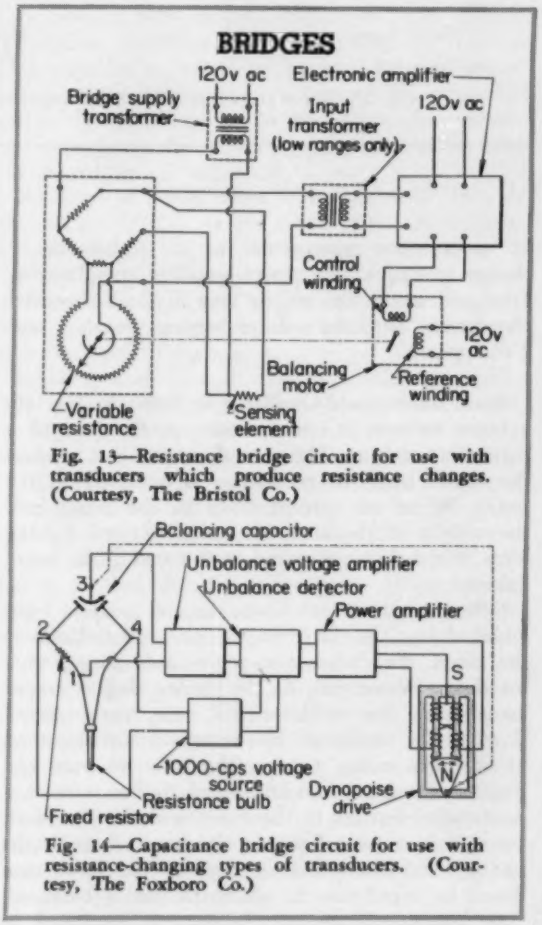


Fig. 13—Resistance bridge circuit for use with transducers which produce resistance changes. (Courtesy, The Bristol Co.)

Fig. 14—Capacitance bridge circuit for use with resistance-changing types of transducers. (Courtesy, The Foxboro Co.)

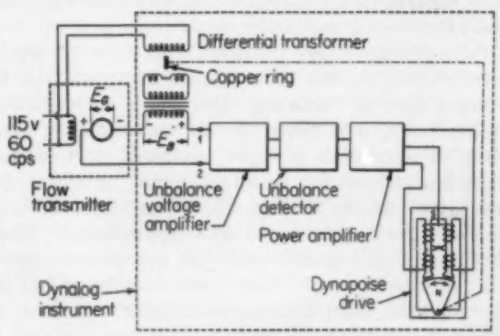


Fig. 15—Differential-transformer measuring circuit for a recorder. (Courtesy, The Foxboro Co.)

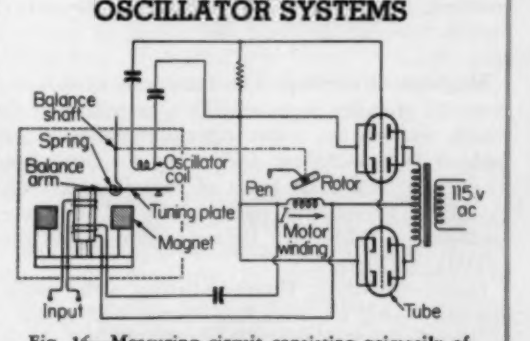


Fig. 16—Measuring circuit consisting primarily of a beam balance and oscillator. (Courtesy, Robertshaw-Fulton Controls Co.)

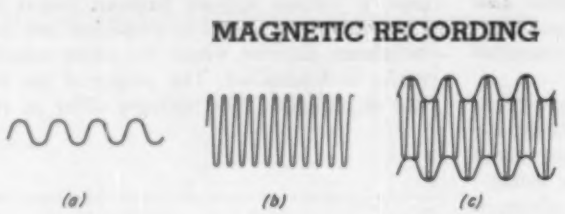


Fig. 17—Wave shapes used in direct magnetic recording.

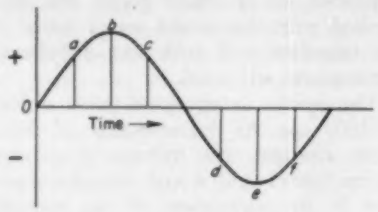


Fig. 18—Sample of a pulse-duration modulation signal obtained from a selector or commutator.

by an amount proportional to the unbalance or change in signal. The power-amplifier energizes the drive and moves the copper ring in the differential transformer until the voltage between points 1 and 2 disappears.

Beam-Balance-and-Oscillator Systems: In Fig. 16, a beam balance is free to move in the field of a permanent magnet. The core of the coil that receives the signal from the transducer is mounted on the beam. When no current flows in the input coil, the weight of the core is counterbalanced by the force of the spring attached to the arm of the beam balance.

When input current flows, the coil exerts a force which draws the core into the coil and unbalances the beam. The beam also serves as a tuning slug for the oscillator coil. As the tuning slug is moved away from the oscillator-tank coil, more current flows in the oscillator. The increased current is fed to the pen motor, causing the rotor to turn and position the pen. Also connected to the rotor is a mechanical linkage to the balance shaft. The shaft turns and exerts a force on the beam through the spring. This force exactly opposes the force produced by input current when the pen is balanced.

A second coil around the core is connected in series with a capacitor. The coil and capacitor are connected in parallel with the pen motor to compensate for sudden changes in pen-motor voltage resulting from rapid line-voltage changes and vibration.

Magnetic Recording: The measuring circuit of a magnetic recorder is an amplifier, or coding device, which receives the input signal, amplifies it, and feeds it to a recording device, the magnetic head. There are four basic types of recording processes: 1. Direct (amplitude modulation). 2. Frequency modulation (FM). 3. Pulse-duration modulation (PDM). 4. Digital.

Direct Recording: Direct recording is the method generally used for recording speech and music or ac signals ranging from 50 to 100,000 cps. In the amplifier, the input signal is amplified, superimposed on a constant high-frequency carrier called a bias, and delivered to the recording head as a varying electric current. The combination of bias and recorded signal is accomplished by a linear mixing process with no new sum and difference frequencies being introduced, Fig. 17. This mixing is not an amplitude-modulation process in which new frequencies are generated.

The high-frequency bias is used so that the magnetic head receives a uniform current that is linear with the input current. Bias is also required because of limitations imposed on the construction of the magnetic head (to be discussed under *Recording Mechanisms*). Direct recording has two limitations: 1. Inability to record low frequencies. 2. Amplitude instability, a condition caused by recording-tape imperfection and resulting in reduction or lapses in signal level (dropouts).

Frequency Modulation: The two limitations present in direct recording are overcome by using the frequency-modulation process. This system uses the transducer signal to frequency-modulate a carrier. When a tape recorded by frequency modulation is played back, the output passes through a demodulator and an electrical filter to remove the carrier frequency and reproduce only the signal frequency.

Frequency-modulated units are used in systems where several different carrier frequencies are modulated by separate input signals. In this way, many channels of signal information can be recorded side by side on a single tape. The FM process is used for recording low-frequency signals and transient signals, and to speed up or slow down a given event by varying the carrier frequency.

Pulse-Duration Modulation: This system permits a number of signals to be recorded on one tape by sharing time of recording. Also called time-division multiplexing, it is based on an instantaneous sampling of a number of signal channels in sequence. Sampling stages for a single signal, a sinusoidal wave, are shown in Fig. 18. When recorded and played back through an appropriate filter, the sampling signals will be reproduced as a full sinusoidal wave. This can also be done for signals other than sine waves or with a number of signals.

When multiple recording is done by the pulse-duration method, a commutator or sequence timer selects transducer signals in sequence and feeds them

to a keyer. This keyer converts the varying-amplitude signals to a constant-amplitude signal for the recording amplifier. The standard system for telemetering is based on the use of 900 samples per second. The total number of samples possible is a function of the number of contacts and the revolutions per second of the commutator.

In addition to producing a signal of constant amplitude, the keyer amplifier also varies the pulse duration for that signal. Normal pulse durations are 90 microseconds for 0 v and 660 microseconds for 5 v full scale, with intermediate values for intermediate voltage signals.

The pulse-duration system is generally used for a number of signal channels of low frequency. Such applications are used in flight testing and engine testing, where a number of transducers are used at one time to sense physical phenomena.

Digital Recording: For the purposes of this article, this process will only be mentioned. A digital recording system is used when recorded data on a tape is to be processed by a digital computer. As in the PDM system, a sampling technique is used to measure a varying signal. The sampled readings are converted to a code consisting only of two digits, 0 and 1, to represent all numbers. These digits are recorded on tape by pulse durations and read out as required.

RECORDING MECHANISMS

The recording means is that portion of a recorder which is actuated by the measuring circuit and which places the recorder output on the recording medium. The type of recording medium determines the method of recording. Methods in general use are: 1. Pen and ink. 2. Light beam, or oscillograph (with photosensitive paper or film). 3. Electric stylus. 4. Thermal or hot stylus. 5. Magnetic head.

The first four types produce a visual record. The magnetic head produces a tape recording which, in the case of direct recording, must be listened to and analyzed or, in the case of frequency modulation, pulse-duration modulation, or digital recording, must be fed to another device to produce a visual record or readout.

Pen and Ink Mechanisms: Pen and ink recorders may use a single pen to draw a single or multiple record on a paper chart, or they may consist of several pens recording a number of variables at the same time. The majority contain one or two pens, although some recorders are equipped with a maximum of nine channels. The use of several channels requires extremely complicated mechanisms to permit the pens to pass one another in making their traces on a chart. If a large number of channels is required, a recorder incorporating the light-beam method is preferable.

To make the recording mechanism as sensitive as possible, its mass is kept to a minimum. The greater the mass, the greater the inertia, and thus, the lower the sensitivity.

The pen is a small capillary tube which may include an integral supply of ink. To reduce inertia and frequent refilling of the supply, the pen is often connected to an ink source by fine capillary tubing, Fig. 19.

The pen may be driven directly from the mechanical output of the measuring circuit. In Fig. 19, the pen travels in an arc about the pivot point. To obtain an accurate trace on the strip chart, the chart is printed with the horizontal lines in an arc to correspond with the pen radius.

Another pen-drive mechanism, Fig. 20, uses a pulley system connected to the drive between servomotor and potentiometer or bridge. As the motor drives the potentiometer, it also drives the recording pen. Since the pen moves in a straight line, the chart lines are horizontal.

Addition of a pen drive to a Dynapoise drive is shown in Fig. 21. As the drive shaft (1) rotates, linkage arms 2, 3, and 4 transmit the motion to the pen arm, 5. Point 6 is a zero-adjusting screw to register the pen point on the chart. The circular-chart radial lines are arcs of a circle to correspond with the travel of the pen.

Reading a curvilinear chart is much more difficult than reading a rectilinear chart. The results of recording first a sine wave and then a square wave on both types of recorders are shown in Fig. 22. Distortion in the curvilinear recording is evident.

Rectilinear motion is obtained with the pen linkage shown in Fig. 23. Arm *PG* is one-half the length of arm *MT*. Point *P* is the mid-point of *MT* and acts as a pivot. Point *G* is the center of curvilinear motion since it is fastened to the moving coil. Point *M* is mechanically restrained to longitudinal motion. According to basic trigonometry, angle *MLT* is always a 90 deg angle for all positions of the link. Therefore, pen point *T* traverses a straight line perpendicular to the restrained motion of *M*.

Multiple-Pen Units: Both strip and circular-chart recorders can be designed for multiple-pen units. In some recorders, the use of four channels requires four separate movements arranged in a row. In such cases, pen movement for each channel is restricted to one-fourth of the width of the chart if no error in time can be tolerated between the movements.

If, however, a small error in time can be tolerated, the pens can be placed one above the other on a common pivot shaft, Fig. 24. Each pen can then write across the full width of the chart.

Single-Pen, Multiple-Trace Units: A single pen can be used to make several records on a single chart. However, the trace is not continuous but consists of a series of dots or dashes.

One type of mechanism which produces multiple traces from a single pen is shown in Fig. 25. Six separate measuring circuits are connected to the multiswitch, which connects each circuit in rotation to the pen drive. In synchronism with this action, an electric motor positions the pen-holding cage to furnish the pen containing the right color of six different-colored inks.

The motor drives cam 1, moves the pen arm from the pen cage toward the chart center and

PEN AND INK MECHANISMS

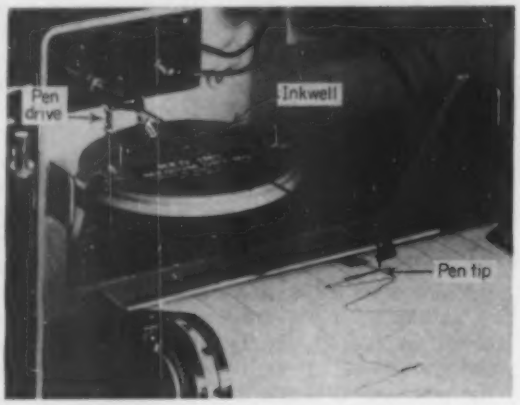


Fig. 19—Recording mechanism for a strip-chart recorder with throwaway inkwell. (Courtesy, General Electric Co.)

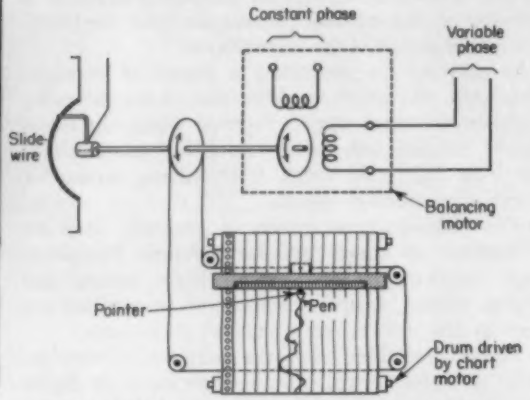
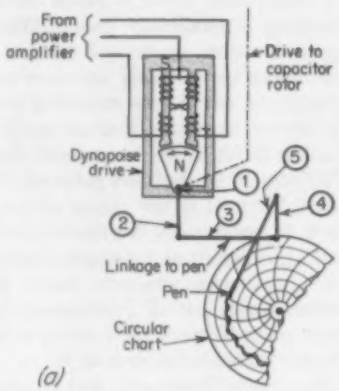


Fig. 20—Pulley system for driving pen mechanism from potentiometer drive of Fig. 10.



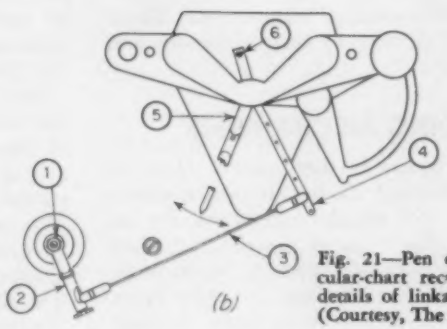


Fig. 21—Pen drive for circular-chart recorder, *a*, and details of linkage system, *b*. (Courtesy, The Foxboro Co.)

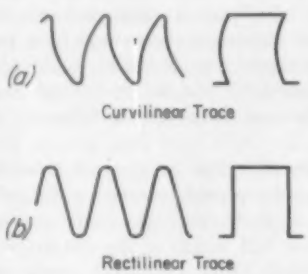


Fig. 22 — Sine and square waves as reproduced on a curvilinear chart, *a*, and on a rectilinear chart, *b*.

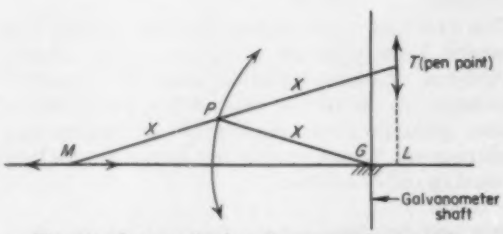


Fig. 23—Pen mechanism for converting rotating motion to straight-line motion. (Courtesy, Texas Instruments Inc.)

back to the pen cage every 6 sec. Each time the pen arm returns to the pen cage, pin 2 shifts the pen cage to the next color pen. The pen point is held to the pen arm by a permanent magnet.

At the same time that a new pen is picked up, the multiswitch connects a new measuring circuit to the pen drive, and shaft 3 positions arm 4 at the correct chart value. Cam follower 5 slides into its recess, allowing flexure strips 6 to carry the pen against the chart. As the motor continues to turn, the pen is lifted from the chart by the flexure strips, returned to the pen cage, and the cycle is repeated. With the chart moving slowly, the successive dots are printed close together. The result is an apparently solid-line record.

Light-Beam Recording: Light-beam recording is accomplished with the use of light-beam galvanometers. A mirror reflects a small spot of light onto light-sensitive chart paper or film and causes a visible trace to be recorded on the chart. Light-beam recorders are called oscillographs and can record

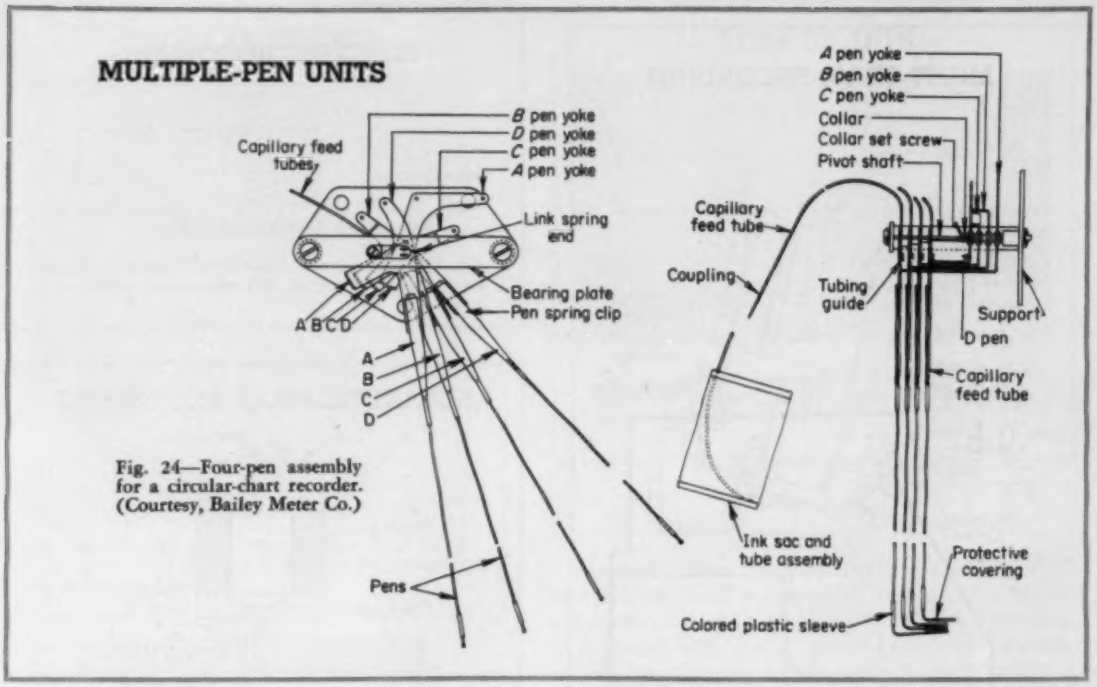


Fig. 24—Four-pen assembly for a circular-chart recorder. (Courtesy, Bailey Meter Co.)

frequencies up to 10,000 cps on as many as 50 channels at one time. Each channel requires a separate light-beam galvanometer.

The optical layout and recording means of one type of light-beam recorder is shown in Fig. 26. A high-intensity mercury-vapor lamp has its light concentrated by the collector lens through the galvanometer lens to the galvanometer mirror. The mirror reflects the light back through the galvanometer lens, through a recording intensity control to the recording mirror, and through the dual cylindrical recording lens. This lens brings the light into sharp focus on the recording plane.

A sweeping-trace identifier interrupts the light beam incident to the galvanometers. This interruption provides brief, sharp breaks in the traces for ready identification of individual traces as they cross and intermix on the recording paper.

The light reflected from the grid-line lamp passes through apertures in a grid-line paper bar to the recording plane.

Electric Recording: Electric inkless recording is accomplished by applying a voltage to a pen point to burn a trace into a metallic-coated paper, Fig. 27. The chart paper is zinc-coated on a wax-impregnated paper. The rheostat controls the voltage applied to the pen, which burns away the zinc to form a trace on the chart paper. The friction contact completes the circuit. The amount of direct current used is approximately 10 ma. The higher the current, the wider the trace.

Thermal Recording: In thermal or heat recording, the pen point is heated so that it melts a coating on the chart paper to produce a trace.

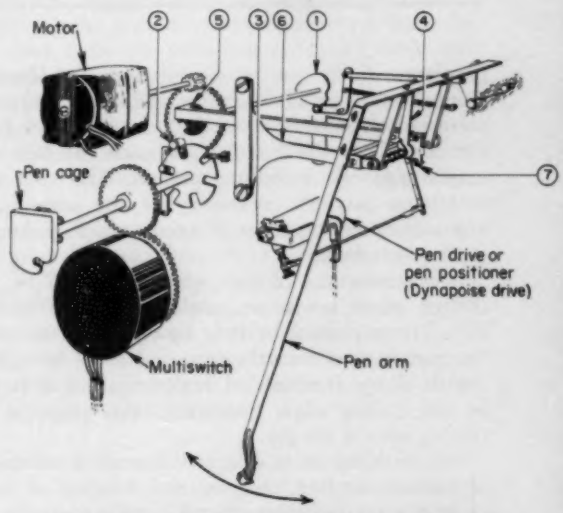


Fig. 25—Mechanism for multiple recording with a single pen arm. In this instrument, six different pen points, each with different-colored inks, are selected in sequence. (Courtesy, The Foxboro Co.)

Magnetic-Head Recording: The recording means in magnetic recorders is the magnetic head. It is made of two identical core halves constructed of thin laminations of a material having high magnetic permeability, low electrical resistance (to minimize eddy-current losses), and good physical wear

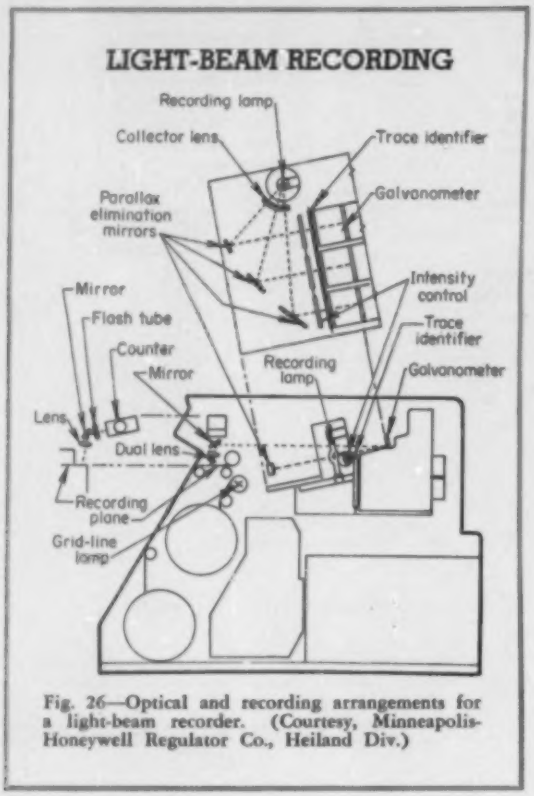


Fig. 26—Optical and recording arrangements for a light-beam recorder. (Courtesy, Minneapolis-Honeywell Regulator Co., Heiland Div.)

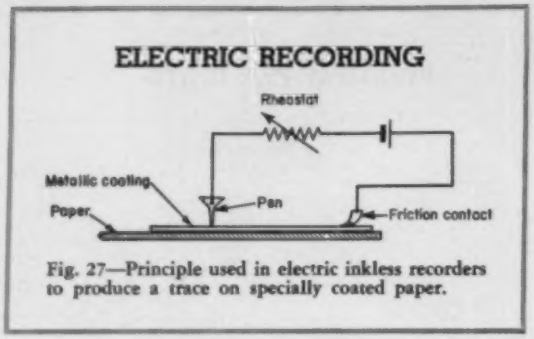


Fig. 27—Principle used in electric inkless recorders to produce a trace on specially coated paper.

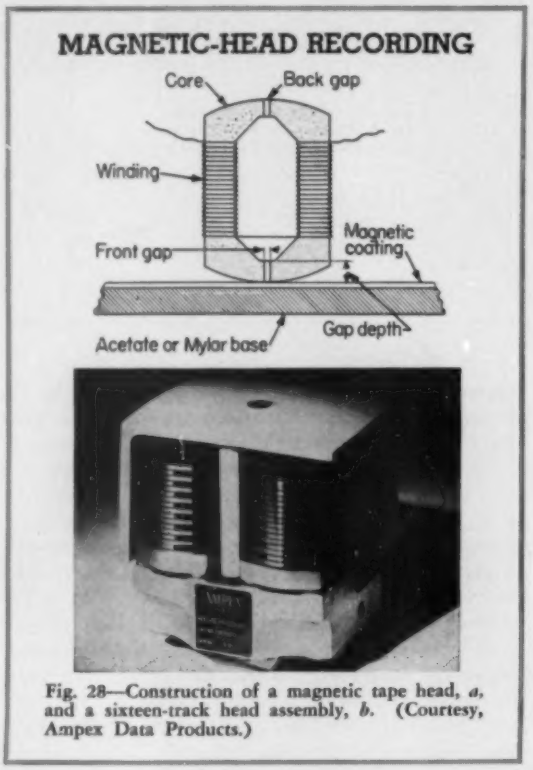


Fig. 28—Construction of a magnetic tape head, *a*, and a sixteen-track head assembly, *b*. (Courtesy, Ampex Data Products.)

properties. Each core is wound with an identical number of turns of fine wire and assembled with nonmagnetic separators for the front and back gaps, Fig. 28*a*. Only the front gap contacts the tape and enters into the recording process. The rear gap maintains magnetic symmetry of the core halves and minimizes the effect of random-hum pickup in the two windings.

A common size of gap width is 0.0005 in., although some heads are made with a 0.00025-in. gap. The gap must be long enough to obtain deep flux penetration into the tape and short enough to obtain sharp gradients of high-frequency bias flux at the trailing edge. Recording takes place at the trailing edge of the gap.

The winding is so designed that the combination of current-carrying capacity and number of turns of wire gives sufficient ampere-turns to provide the necessary bias magnetization for direct recording or to saturate the tape for other recording methods. Head assemblies can be made to include a number of recording gaps, Fig. 28*b*.

RECORDING MEDIUM

The type of recording medium depends on the recording means that is used. In all types of recorders, the paper or tape should not be adversely affected by atmospheric temperature and humidity. Any abnormal stretch or shrink in the chart paper or tape causes inaccurate recordings.

For pen and ink recording, the surface of the paper must be absorbent enough to receive the ink, yet hard enough to resist spreading the ink. An extremely hard-surfaced paper causes unnecessary wear on the pen tip.

Papers for use with electric and hot styli are specially coated. For use with electric styli, the paper generally has a zinc or aluminum coating which burns away when current passes through the pen. For hot styli, the paper can be wax-coated or coated with a special oxide which turns black when heated. When these coatings are applied to transparent paper, the recording may be reproduced in blueprint or whiteprint equipment to obtain additional copies.

Chart paper is also available that will reproduce a trace with a plain pointed stylus. It is similar to carbon paper in that the carbon is removed when contacted by the pen.

CIRCULAR CHARTS

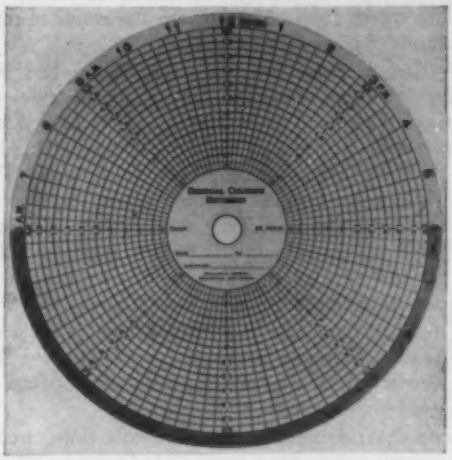


Fig. 29—Circular chart, 7⅝-in. diam, used for a 24-hr record in a Wallace & Tiernan Inc. recorder for residual chlorine.

STRIP CHARTS

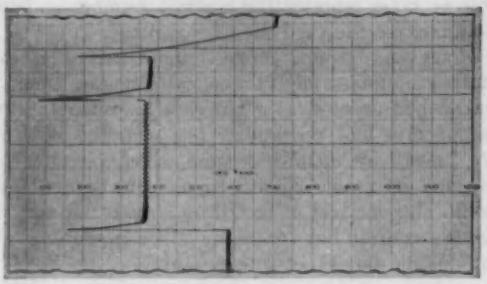


Fig. 30—Strip chart, 10¾-in. wide, for use in recording temperatures on preprinted grid lines. (Courtesy, Leeds & Northrup Co.)

Light-beam galvanometers or oscillographic recorders use photosensitive paper or film to record the light-beam trace. Two types of photosensitive paper are used. One requires darkroom developing, so must be protected from light. The other is not sensitive to normal room light but reproduces the intense light of the recording mechanism.

Circular Charts: Circular charts vary from several inches in diameter to 12 in., Fig. 29. Since charts do not print to the center, and since the outer rim is generally printed with the time period covered, less than one-half the diameter is available for the printed record. Charts are generally printed for 2, 4, 8, 12, or 24-hr, or 7-day periods. Since only 360 deg is available for recording, the increased period of time compresses the trace. If there are wide fluctuations in a process system, a 7-day chart will probably give a poor record. In such a case, a 24-hr chart will spread the trace and increase the definition seven times.

Strip Charts: Paper requirements for strip charts are the same as those for circular charts, namely, resistance to temperature and humidity. Strip charts vary from a few inches in width to 12 in. A 12-in. strip chart presents 11 in. of printing surface—the balance being used for driving the chart.

Miniature recorders permit more recorders to be placed on control panels. These recorders are made with charts as narrow as 2 in.

For pen or stylus recording, charts are preprinted. Grid lines for the chart used with the recorder shown in Fig. 26 are printed by light while the recorder is operating. A typical preprinted strip chart used in a temperature recorder is shown in Fig. 30. Strip charts are available with a maximum of 500 ft of chart per roll, but the quantity depends on the recorder being used.

Magnetic Tapes: Magnetic tapes are usually 0.001 to 0.0015-in. thick and from ½ to 1-in. wide. Mylar, a polyester material, is the most common tape base. It is coated with finely ground iron-oxide particles, which become magnetized when passed under a recording head. The tape is supplied in reels with up to 3600 ft in one roll.

Defects in magnetic tape result in dropouts. This condition can be caused by areas in the tape which receive low magnetization or none at all, or by nodules on the surface of the tape which force the tape away from the recording head and cause low magnetization at that point. Dropouts are not as serious in direct-frequency modulation or pulse-duration modulation as they are in digital recording. In digital recording where 200 pulses per inch of tape are possible, dropouts can easily delete some of the pulses.

To minimize wear on tape, the rub-off of iron oxide onto the recording head, and wear on the head, a plastic coating is applied to certain types of magnetic tape. The coating, however, causes a 50-microinch separation of the head and tape. As a result of this air gap, there is a slight reduction in high-frequency response, which is not critical for most industrial applications.

Magnetic Drums: Generally, a magnetic drum is used as a device for storing information, not necessarily as a recorder. The drum may be likened to a cylinder wrapped with magnetic tape one layer thick from end to end. The recording and reading heads are mounted adjacent to the drum.

Because of their speed of input and output, magnetic drums are used as buffers in the operation of computers. Information from slow-speed input devices is stored in the drums to feed the rapid needs of the computers.

Punched Cards: Cards perforated with holes according to a specific order may be used for recording or storing information. A typical card has 80 vertical columns. Each column accommodates a

hole or holes representing a single number or letter. Columns on the card may be grouped.

Holes and groups properly punched on a card represent stored information, which can later be transcribed or used as a program in process control or machine-tool operation. The punches or holes are "read" by metallic fingers which operate electric and electronic circuits to perform desired functions. This method of recording is used not only for process control but for many office operations and for feeding data-processing systems.

RECORDER DRIVES

Drive systems for recorders are classified primarily by the recording medium, being either chart drives or tape drives.

Chart Drives: Drives for circular charts and strip charts can be: 1. Synchronous motors. 2. Spring motors. 3. Motor-driven wound springs.

The speed of chart movement is generally determined by the frequency of the recording signal. The higher the frequency, the faster the chart must move to produce a trace having good definition. Fig. 31 shows the same sine-wave signal recorded at three different chart speeds. Recording frequency and amplitude are the same for each, but the chart speed has been varied. A variation in chart speed is accomplished by changing the gear ratio on the output shaft of the motor. Some commercial units have built-in transmissions; others require that the complete motor mechanism be changed. Chart-drive speeds depend on the application of the recorder. Circular charts are usually driven at 1 revolution per 24 hr or, at slowest speeds, 1 revolution per week. Strip-chart drives vary from $\frac{1}{8}$ in. per min to 400 ips for extremely high frequencies.

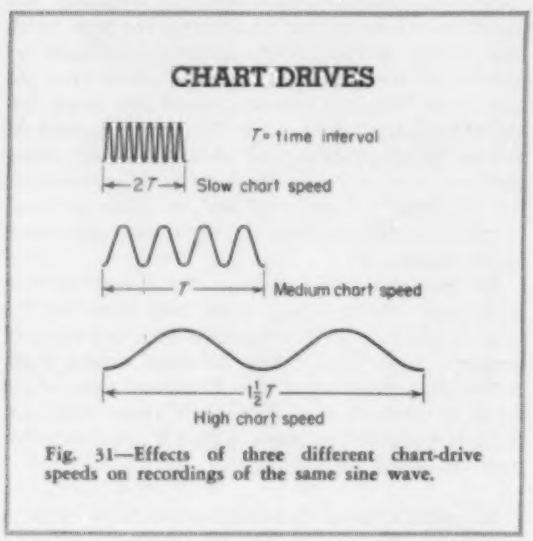


Fig. 31—Effects of three different chart-drive speeds on recordings of the same sine wave.

Synchronous motors produce the most uniform driving speed. Any variations are the result of minor variations in power-line frequency.

If there is danger of prolonged power loss, or if power is not available, a spring-wound drive can be used. These drives, however, are not used with high-speed strip charts because a spring becomes too bulky for a prolonged period of operation. Temporary interruptions in recording as a result of power failure are compensated for with spring-drive units wound by electric motors. If there is a power failure, the wound spring continues to drive the chart for periods up to 12 hr.

Circular charts are generally driven from a center spindle, although some are driven about a floating center by a friction drive which contacts the outer edge of the chart.

Strip-chart drives are more intricate than circular-chart drives since they must include a spool for the supply roll and a means of rewinding the chart paper after recording. Strip charts are generally driven by a sprocket which engages holes punched in the edge of the paper, Fig. 30.

Tape Drives: A simplified version of a tape drive is shown in Fig. 32. The supply reel feeds out the tape and provides a braking action to ensure good contact of the tape with the head. The supply reel is also connected to a motor drive for rewinding. The inertia roller is used to smooth out variations in tape speed. The capstan meters the tape at constant linear velocity. The take-up tension arm is a spring-loaded idler which takes up the normal slack caused when tape motion is first started. The take-up reel rolls up the tape during playing.

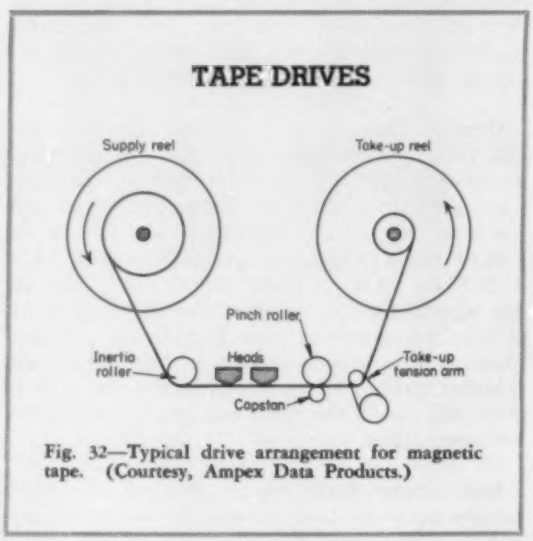
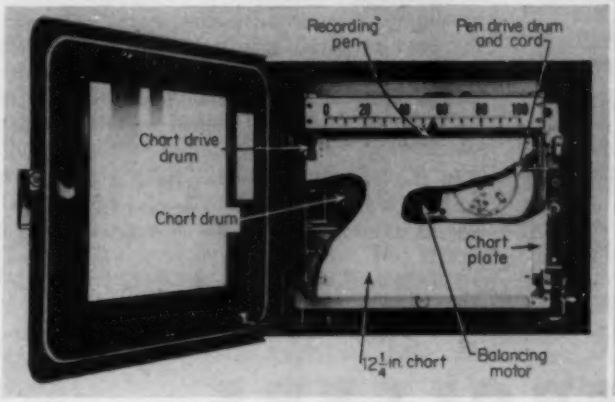


Fig. 32—Typical drive arrangement for magnetic tape. (Courtesy, Ampex Data Products.)

The speed of the tape across the recording head is critical, particularly in frequency-modulation re-

SPECIAL FEATURES



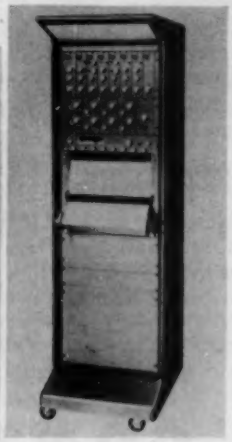


Fig. 33—Strip-chart recorder with scale and pointer to indicate the instantaneous value being recorded on the chart. (Courtesy, The Bristol Co.)

Fig. 34 — Oscillographic recorder in a lighted cabinet mounted on rollers. (Courtesy, Offner Electronics Inc.)

cording. Variations in tape speed cause extraneous or incorrect frequency recordings called flutter and wow. These errors add noise to an FM system, introduce signal errors in pulse-duration modulation recording, and distort the time base of any recording.

Alignment of the tape on the idlers and capstan must be accurate and is of prime importance in digital recording of multiple channels. Any skew in the tape will record some channels out-of-phase with relation to other channels of information.

Tape drive speeds are commonly 1⅞, 3¾, 7½, 15, 30, and 60 ips.

SPECIAL FEATURES

In addition to the four basic sections of recorders, extra accessories and apparatus are included with many recorders. The method of mounting and removing circular charts can be a magnetic catch or a threaded nut. Special types of pen lifters are built-in for easy removal of charts. Most recorders, however, include calibrating means to properly zero the pen when no signal is applied.

Often the recording mechanism is used to transmit its operating signal to a remote recorder. Such an installation permits recording both at an operating station and at a control panel which includes all the operating points of a process system. The transmitting means is frequently a potentiometer, the rotor of which is driven at such a speed and to such a position as to give a signal output proportional to the position of the pen in the primary recorder.

The potentiometric strip-chart recorder shown in Fig. 33 includes an indicator at the top of the case.

X-Y RECORDERS

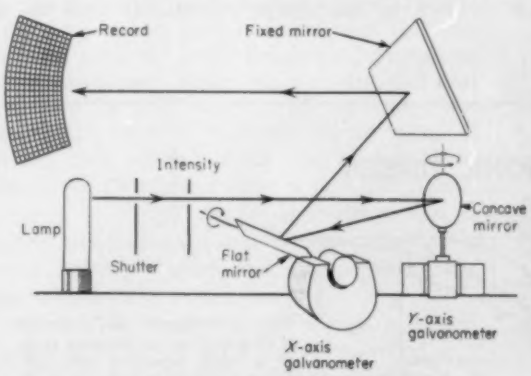


Fig. 35—Optical system used with light-beam galvanometers in *x-y* recorder. (Courtesy, Sanborn Co.)

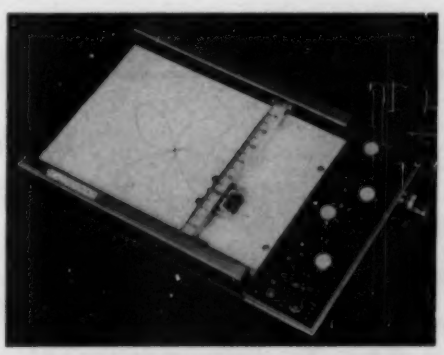


Fig. 36—Direct recording with pen and ink on *x-y* recorder. (Courtesy, F. L. Mosley Co.)

The direct-writing oscillograph shown in Fig. 34 produces records rectilinearly with heat or electricity or curvilinearly with ink or electricity on a paper chart. Eight channels can be recorded simultaneously with a frequency response beyond 150 cps and a deflection time less than 1.5 millisecond.

X-Y RECORDERS

Plotting two variables on a recorder at the same time to obtain their relationship to one another can be accomplished with x-y recorders. In a circular-chart or strip-chart recorder, one function is connected to the pen drive. The second function replaces the normal time-controlled chart drive and drives the chart at a speed proportional to the variations of the second function. Such an arrangement is used in the light-beam galvanometer system shown in Fig. 35. One variable controls the x-axis galvanometer, and the other variable controls the y-axis galvanometer. The final record is a rectangular chart with the two variables plotted in relation to each other.

In the x-y recorder shown in Fig. 36, the functions of x and y are fed to a mechanical unit that records directly in Cartesian co-ordinates on a large chart.

CONTROLLERS

In a control system, the controller is the unit which produces, transmits, or monitors a signal to the final control element or actuator. The controller can be electronic, electric, hydraulic, pneumatic, mechanical, or a combination of these types. Methods for operating the controller are: 1. A timing mechanism, as in program controllers. 2. A transducer signal, as in automatic controllers.

TIMERS

The simplest type of process controller is a timer. The major kinds of timers are mechanical, electromechanical, electronic, and thermal.

Mechanical Timers: Most mechanical timers are spring driven with some form of escapement to control the spring power. As the spring unwinds, cams on the output shaft operate relays or switches which open or close electrical circuits according to a predetermined interval or time of day. Two examples are the timers used in household thermostats and automatic kitchen ranges. At the end of the timed period, the spring must be rewound or the timer reset for the next timed interval, which may range from a few minutes up to 24 hr, depending on the type of timer used.

Electromechanical Timers: Electromechanical timers consist of a cam or series of cams driven by an electric motor. The drive can be a direct type or an electric clutch. To obtain the desired accuracy, a synchronous motor is generally used.

An electric clock which rotates cams to trip a chiming mechanism every hour is a typical electromechanical timer. The same system can be used for programming a complete control system. One complete operation can be performed in part of a minute, or the cycle can be measured in days.

Electronic Timers: Most electronic timing devices operate from a single, basic, electrical principle, namely, that time is required to charge a capacitor to its full charge. The more resistance in series with the charging voltage, the longer the time required to fully charge the capacitor.

For example, the capacitor in Fig. 37*a* does not reach its full charge immediately after the switch

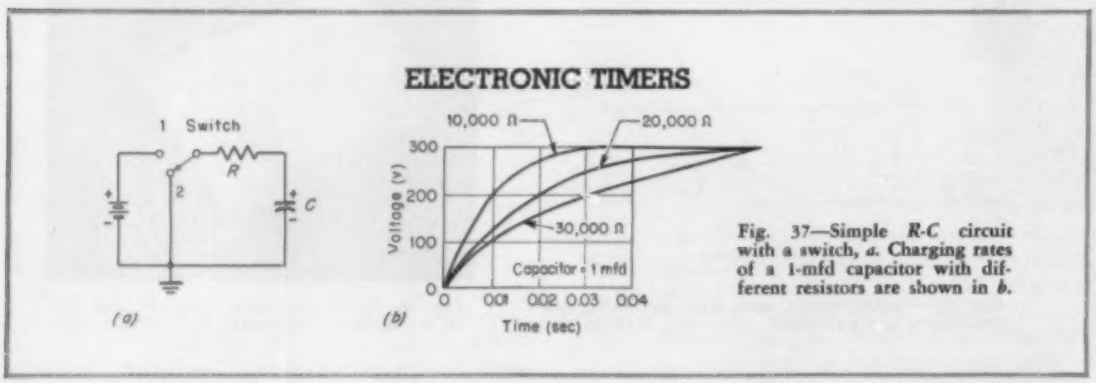


Fig. 37—Simple *R-C* circuit with a switch, *a*. Charging rates of a 1-mfd capacitor with different resistors are shown in *b*.

is thrown to position 1 because the resistor reduces the electron current in the circuit. If the switch connects the battery to the capacitor for a sufficient period of time, however, the total charge on the capacitor will always become the same regardless of the value of the resistor. The capacitor can supply (or store) only a finite number of electrons. This total number of electrons depends upon the area of the capacitor plates and the applied voltage. Generally, a capacitor rating is a value of capacitance at a particular voltage.

The curves in Fig. 37*b* show the time required for a 1-mfd capacitor to charge to a value of 300 v through different values of resistance. The time required to charge a capacitor through a resistor to 63 per cent, or about two-thirds, of the supply voltage is equal to $R \times C$, where R is the resistance in ohms and C is the capacitance in farads. Also, when a capacitor is fully charged, the time required for it to discharge through a resistor to 37 per cent, or about one-third, of its original value is equal to $R \times C$. This value is the "time constant" of the R-C circuit.

If a 1-mfd capacitor is connected to a potential of 300 v through a 10,000-ohm resistor, Fig. 37*b*, the capacitor will charge to a value of 200 v, approximately, in 0.01 sec (0.000001 f × 10,000 ohms). If R is increased to 20,000 ohms, then 0.000001 f × 20,000 ohms = 0.02 sec.

If the same capacitor and the 10,000-ohm resistor are connected to a potential of 600 v, the time constant will be exactly the same. The difference is that the capacitor will charge to 400 v (two-thirds of the new supply voltage) in the same length of time, 0.01 sec. Longer time intervals can be accomplished by increasing both values. For example, when a 10-mfd capacitor is charged through a 1-megohm resistor, the time constant equals 0.000010 f × 1,000,000 ohms, or 10 sec.

Electronic timing devices use an R-C time constant in either the grid or plate circuit of a tube to provide an initial timing signal. If this signal controls a specific period of time before an action takes place, the circuit is a time-delay circuit. The timing signal can also control the length of time that a circuit is permitted to operate. For example, in electronic timing of resistance-welding circuits, one electronic timing circuit synchronizes the start of the weld with the power-line frequency; another electronic timer controls the length of time that heat is applied to the weld; and a third electronic timer determines the length of time that the two pieces of metal are held together while the weld hardens.

Thyratrons: One type of electron tube that is commonly used in timing circuits is the thyratron, a thermionic gas-filled tube that has three elements—a heated cathode, a plate, and a grid. Thyratrons are also made with more than one grid.

A thyratron is designed specifically as a control device and is therefore called a grid-controlled rectifier. A control signal that drives the grid positive causes the tube to conduct. Because of the presence of gas in the tube, ionization takes places instantly. Once the gas throughout the tube is ionized, the grid can no longer control the action of the tube. The tube continues to conduct as long as there is sufficient difference in potential between cathode and plate.

The thyratron grid, then, can control conduction through the thyratron only before conduction starts. Thus, a thyratron can be used only as a starting mechanism. In dc operation, a thyratron tube continues to conduct, after once started, regardless of the condition of the grid. Therefore, some other action, such as a drop in plate potential, must be instituted before conduction stops.

The thyratron finds its greatest application in ac circuits where the plate is positive only one-half the time. As a result, current flows through the tube intermittently. At the end of each conduction period (each cycle of the alternating current) the grid regains control. Thus, the total current which flows in each cycle of the ac wave can be varied by changing the instant in each cycle in which the grid starts the tube to conduct.

A second grid can be added to the thyratron to shield the first grid and reduce the coupling between plate and the first grid. The second grid can also be used to provide dual control of conduction. In such tubes the exact instant of conduction is controlled by the combination of two signals rather than a single signal.

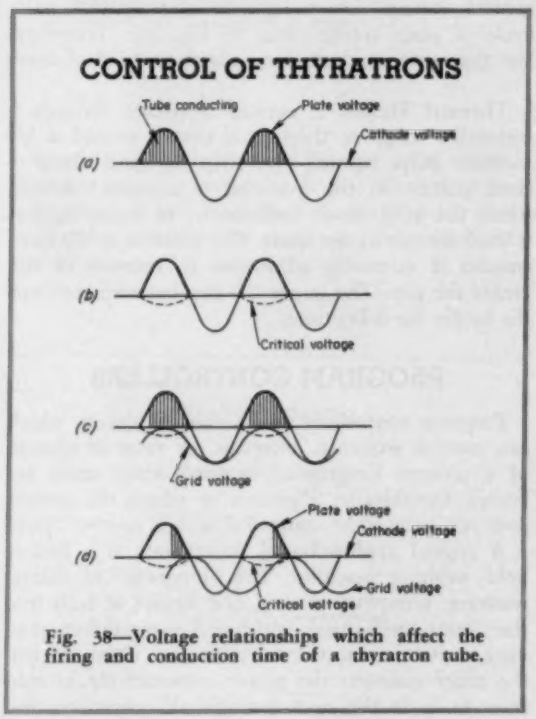


Fig. 38—Voltage relationships which affect the firing and conduction time of a thyratron tube.

Control of Thyratrons: When the grid of a thyratron is maintained sufficiently positive with respect to the cathode, conduction takes place as soon as the plate potential swings in a positive direction, Fig. 38*a*. When the ac wave form applied to the plate

of the tube swings negative with respect to the cathode, the thyratron cannot conduct.

As plate voltage swings more positive, an increasingly greater negative voltage must be applied to the grid to prevent conduction. This value of grid voltage is called the critical voltage. How this negative grid voltage must vary with plate voltage to keep the thyratron from conducting is shown in Fig. 38*b*. Note that the critical voltage must be 180 deg out of phase with the plate voltage.

If the voltage applied to the grid is other than exactly 180 deg out of phase with the plate voltage and reaches a magnitude at least equal to the critical voltage, the thyratron can be made to conduct merely by shifting the phase of the ac grid voltage. In Fig. 38*c*, grid voltage and plate voltage are exactly in phase. The thyratron begins conducting each time the grid voltage exceeds the critical voltage. The thyratron continues to conduct until the plate voltage is reduced to the level of the cathode voltage or below it.

In Fig. 38*d*, grid voltage lags plate voltage by 90 deg. The point at which grid voltage exceeds the critical voltage occurs later in the positive half-cycle of plate voltage than in Fig. 38*c*. Therefore, the thyratron conducts for a shorter period of time.

Thermal Timers: A current is passed through a bimetallic strip, or through a heater around a bimetallic strip, causing the strip to bend about a fixed point. On the free end is a contact which, when the strip bends sufficiently, is forced against a fixed contact in the timer. The position of the fixed contact is manually adjustable to increase or decrease the gap. The larger the gap between contacts, the longer the delay time.

PROGRAM CONTROLLERS

Program controllers are a class of timers which can control sequence, intervals, or rates of change of a process. Programing is used when there are known variables in a process or where the process does not have to be controlled within narrow limits.

A typical application of programing is a household washing machine. The "program" of filling, washing, pumping, rinsing, and drying is built into the timing mechanism, which is a motor-driven stepping switch connected to solenoids. Once started, the timer connects the power consecutively to contacts to cycle the unit through all operations and automatically shuts it off when the cycle is complete.

Another type of program controller, Fig. 39, consists of a series of cams mounted on a motor-driven shaft. The actuator of a switch rides on the periphery of each cam. The cams are shaped and positioned so that the switches are operated in a predetermined sequence. The switches control the actuators in a system.

A third type of program controller, Fig. 40, uses a chart cut as a cam. The chart (program) is rotated by a synchronous motor so that one revolution covers the desired period of time. After one complete revolution, the program cycle is repeated. In place of a pen arm, as in a recorder, a roller mounted at the end of the arm rolls on the periphery of the cam. A program controller of this type permits partial operation of an appropriate type of actuator as opposed to the cam-operated or cycle timer, which provides on-off operation.

AUTOMATIC CONTROLLERS

Many control systems which require accurate and fast response use automatic controllers. On an overall basis of installation, operation, and maintenance, automatic controllers are often cheaper than program or manual systems. Many automatic controllers have recorders or indicators, or both, built into the same housing to provide visual indication or records of the operation.

Although automatic controllers appear to be an ideal solution to process control, there are physical characteristics of a process which can delay the changes which are called for. These delays and required changes increase the difficulty of control, require special attention to the location of the transducer, and affect the mode of control selected. The delays, termed process time lags, include capacity lag, transfer lag, and dead time.

For example, in a hot water or steam home-heating system, the transducer and controller are the thermostat. When the thermostat calls for heat and turns on the gas or oil, a capacity lag is encountered. Capacity lag is caused by those parts of the system which have the ability to store energy. In this example, the water in the boiler must be heated. The larger the volume of water, the greater the capacity lag.

At about the same time, transfer lag becomes a factor to cope with. Transfer lag is caused by those parts of the system which resist the transfer of energy. In a home-heating system, these parts are represented by the walls of the boiler and scale and sediment in the boiler. The radiator walls can also cause transfer lag.

Dead time is the time required to carry a change from one point to another in a process. In this example, dead time is the carrying of heat from the boiler to the thermostat so that the thermostat can shut off the fuel supply.

A controller consists basically of a means of measuring the transducer output. It compares the output to a desired value called a set point, determines the error or deviation between transducer output and the set point, and produces a counteraction to maintain the smallest possible deviation. Producing the counteraction is also called characterization of the controller output signal, and the method is called the mode of control.

The modes of control available are: 1. Two position, also called on-off control. 2. Three position. 3. Differential gap. 4. Floating control. 5. Proportional. 6. Proportional-reset. 7. Proportional-reset-rate.

Two-Position Control: On-off controllers can op-

erate actuators at only two positions, which are generally preset at minimum and maximum. For example, in a home-heating system, a thermostat is set for 70 F. With house temperature below 70 F, the boiler delivers heat. When house temperature reaches the thermostat set point, the fuel valve is closed. However, the temperature slightly overrides the set point before falling. When the temperature again falls below the set point, the fuel valve is fully opened, and the cycle repeats.

Two-position control is best suited to high-capacity processes with minimum dead time.

Oscillators: One application of an oscillator as an on-off controller is shown in Fig. 41. A metal vane crosses the axis of coils L_1 and L_2. The meter movement is connected to a thermocouple to sense the temperature in an oven.

As oven temperature increases, the pointer connected to the meter movement, Fig. 41*a*, moves upscale, and the metal vane attached to the pointer arm moves between coils L_1 and L_2. The preset temperature level is determined by the physical position of L_1 and L_2.

As the metal vane moves between the coils, Fig. 41*b*, it tends to absorb some of the magnetic field that produces the inductive coupling. When the pointer moves up-scale to a position where the metal vane absorbs a large part of the magnetic flux between L_1 and L_2, the tube ceases to oscillate, and plate current is reduced. With insufficient plate current flowing through the relay, the relay is de-energized, the relay contacts open, and the fuel supply (electric heater) to the oven is cut off to prevent the temperature from going higher.

When the temperature falls, the indicator pointer carries the metal vane out of the magnetic field between coils L_1 and L_2. As a result, the tube again begins to oscillate, current flows in the plate circuit, and the relay is energized. When the relay contacts close, the heater is supplied with power to bring the temperature of the oven up to its preset level.

A similar type of circuit is used in the automatic system for leveling an elevator car at each floor. A metal vane is controlled to interrupt an oscillator circuit when the elevator floor is exactly level with the floor of the loading area. The metal vane quenches the oscillator, de-energizes the relay, and opens the circuit to the elevator drive motor.

Photocells: Another type of controller similar to the oscillator type uses a light source and a photocell on the set-point arm. A metal vane interrupts the light beam, which causes a drop in the voltage output from the photocell.

Usually, the output from the photocell is connected to an amplifier which produces an output only when it receives a positive bias voltage from the photocell. When the voltage output of the photocell drops, the amplifier output becomes too small to maintain energization of a relay. Thus, the load circuit is opened just as in the oscillator-type controller.

Three-Position Control: With three-position control, the final control element (actuator) assumes one of three fixed positions, each of which corresponds to a selected zone of the controlled variable. Assume that a thermostat is set to control heat between 68 F and 72 F. Because of the process lags, the system overrides the maximum and undershoots the minimum.

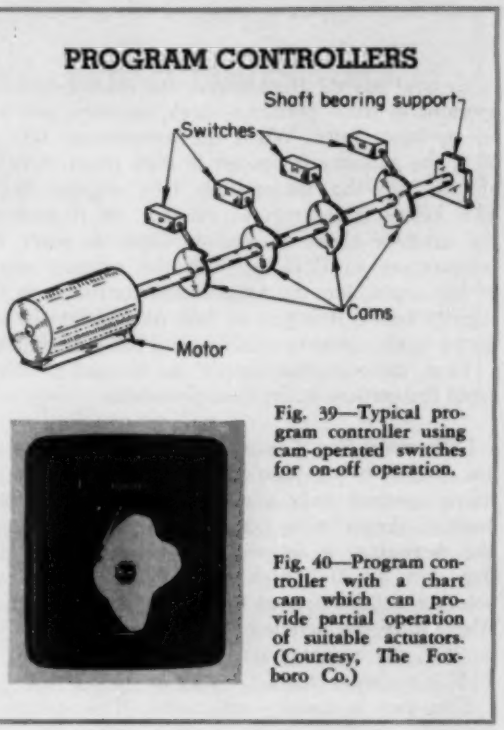


Fig. 39—Typical program controller using cam-operated switches for on-off operation.

Fig. 40—Program controller with a chart cam which can provide partial operation of suitable actuators. (Courtesy, The Foxboro Co.)

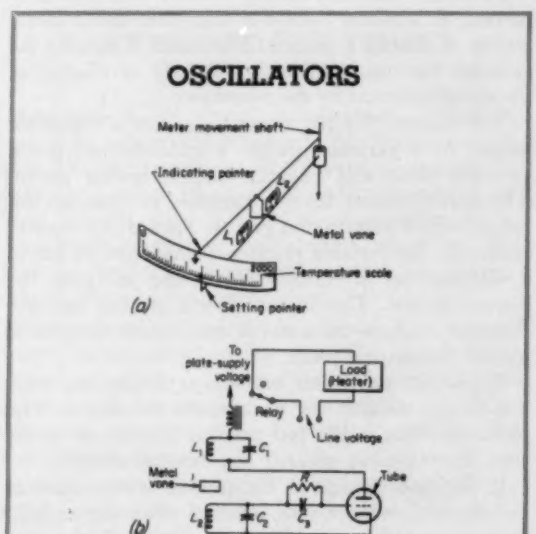


Fig. 41—Use of an oscillator as an on-off controller. Physical arrangement of the control elements is shown in *a;* the control circuit, in *b*.

To level out the fluctuations, the control device is operated at three positions—*high*, *medium*, and *low* energy-input rates. When the temperature falls to 68 F, the actuator is opened to *high* input. Because of the lag, the temperature falls slightly below 68 F before it recovers to increase. As it recovers, the actuator closes to *medium* input to carry the temperature to 72 F. At 72 F the actuator closes to *low* input, but the temperature continues to rise slightly before it begins to fall. As it falls, the actuator again opens to *medium*, and the cycle repeats.

Thus, three-position control can be used to reduce rapid fluctuations in the control variable.

Differential-Gap Control: Differential-gap systems are similar to two-position controls in that the actuator assumes only a minimum and a maximum position. Again using home heating as an example, the thermostat is set with a differential gap of 2 deg—*low* at 70 F, *high* at 72 F. Below 70 F the actuator is fully opened for maximum energy input. Above 72 F the actuator is fully closed. From 70 F to 72 F, the actuator is always open; from 72 F to 70 F, it is always closed.

The gap is usually adjustable. This system is generally used in home heating rather than the simplified version described under *Two-Position Control*.

Both the oscillator control circuit and the photocell control circuit described under *Two-Position Control* can be operated as three-position and differential-gap controllers. Once a second set point (a *low* set point) is added, the actuating relays are connected to give the desired type of control.

Floating Control: Floating control is a means of moving an actuator toward a maximum or minimum setting to control a process. The speed of moving the actuator has no relation to the rate of change of the variable sensed by the transducer.

The electric floating control requires a reversible motor. As a variable reaches a minimum set point, contacts close and energize the reversible motor. The motor rotates in one direction to open an actuator which returns the process toward the neutral point. As the variable reaches a maximum set point, a different set of contacts closes and energizes the control motor. The motor rotates in the opposite direction to close the actuator and return the process toward the neutral point.

While the controlled variable is within the neutral zone, neither set of contacts is closed. The motor remains in the last position it attained at the time the variable entered the neutral zone.

If the rate change in the process is too rapid to be brought back to the neutral zone by a fully opened or fully closed actuator, limit switches are provided on the floating-control motor. The limit switches open the circuit to the motor to prevent overtravel.

Floating control can also be applied to hydraulic controllers. In any case, however, the corrective action of floating control is slow and cannot be used in processes with fast load changes.

Proportional Control: In proportional control, the controller transmits to the actuator a signal directly proportional to the magnitude of the signal from the transducer. The ratio of the variation in transducer signal (in per cent of full-scale) to the variation in controller output (in per cent of full scale) is called the proportional band.

If 100 per cent variation (0 to full scale) of the transducer signal produces a 100 per cent variation (0 to full scale) in output signal from the controller, the proportional band of the controller is 100 per cent. If the transducer signal varies by 40 per cent and produces a 100 per cent variation in output from the controller, the proportional band is 40 per cent. If the transducer signal varies from 0 to full scale and produces a 50 per cent variation in controller output, the proportional band is 200 per cent. The relationship of a controlled or measured variable to controller-output signal in a controller having a proportional band of 200 per cent is shown in Fig. 42.

Control units are available with proportional bands varying from 10 per cent or less up to 600 per cent. The smaller the proportional band, the greater the proportional sensitivity, or, the more precise the control. In most controllers the proportional band

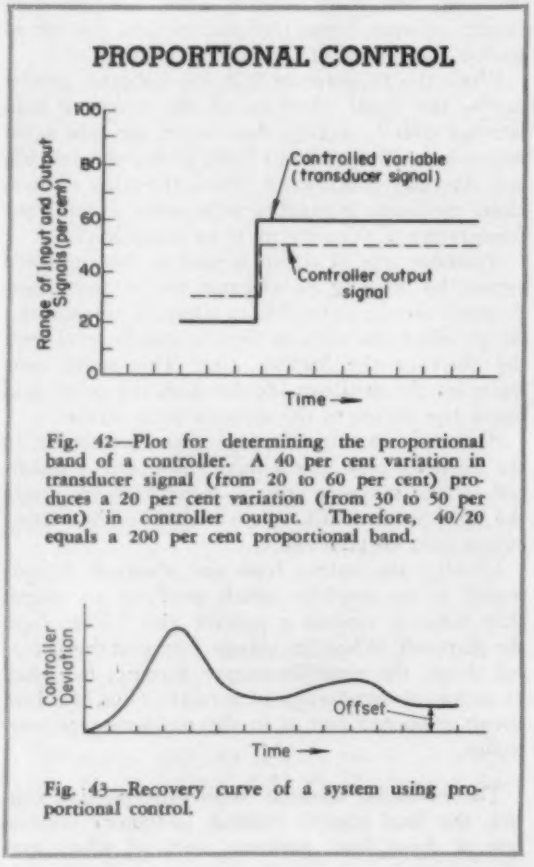


Fig. 42—Plot for determining the proportional band of a controller. A 40 per cent variation in transducer signal (from 20 to 60 per cent) produces a 20 per cent variation (from 30 to 50 per cent) in controller output. Therefore, 40/20 equals a 200 per cent proportional band.

Fig. 43—Recovery curve of a system using proportional control.

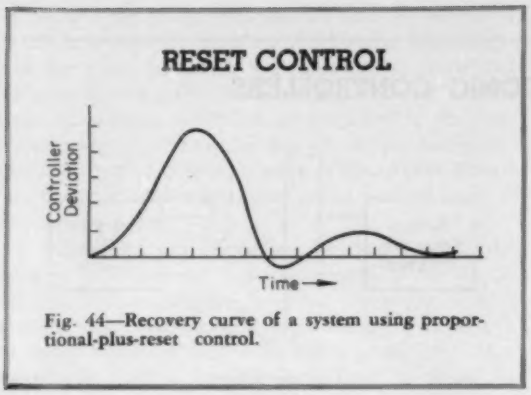


Fig. 44—Recovery curve of a system using proportional-plus-reset control.

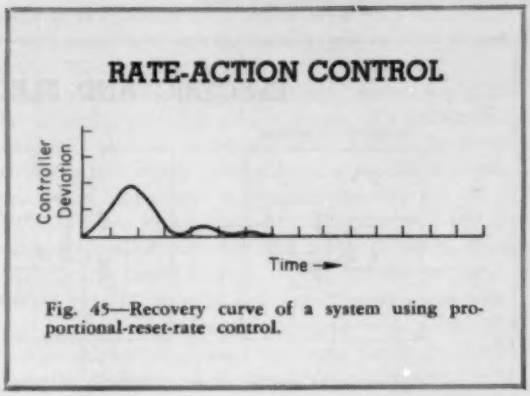


Fig. 45—Recovery curve of a system using proportional-reset-rate control.

can be manually set.

The purpose of proportional band and proportional sensitivity is to permit maximum actuator movement with small process variations or to produce small actuator movement from large variations.

Processes controlled only by proportional action always result in a small difference between controller set point and the value of the controlled variable. This difference is called offset. Reducing the proportional band can reduce the offset; but if the band is made too narrow, the system becomes unstable. The increased sensitivity of the system results in constant hunting or continuous actuator movement. Variations sensed by a transducer recover according to the curve shown in Fig. 43 when only proportional action is used in a controller.

Reset Control: The offset resulting from a proportional-action system can be reduced by adding a reset action to the controller. Reset action totals the error signal in the controller over the period of time the error exists; that is, the controller reacts to the length of time that the deviation is away from the set point. Thus, the summation of the error signal produces a larger output signal from the controller.

This system is also called integral control. The name is derived from the mathematical formula for determining rate. Reset is expressed in time (minutes), being the period of time or cycle when reset action acts to return the controlled variable to the set point. The output signal from the controller is a total of the proportional error and the reset signal.

Although the reset feature reduces the offset resulting from proportional control, a proportional-plus-reset controller lags behind the deviation signal by a certain amount. This lag results in an increase in the amount and period of disturbance in the controlled variable, Fig. 44. Note that the offset is reduced, but there is a larger displacement of the signal and a longer time interval between the two maximum values of the cycle curve.

Rate-Action Control: To reduce the signal lag and larger deviation resulting from reset action, rate action is used. Rate action of a controller causes the output signal to vary as the rate of change of the error in the controlled variable, or in accordance with how fast the change occurs. Thus, the faster an error changes, the larger the controller output signal.

This feature is combined with proportional-reset action to give the closest control of a process system. Rate action is expressed in time (minutes), being the period between the rate signals necessary to return the controlled variable to the set point.

A typical recovery cycle for a controller using proportional-reset-rate action is shown in Fig. 45. At the beginning of a variation, the controller output signal is larger (its deviation less) than it would be for proportional control alone. Also, there is a faster return to the set point of the controller.

Rate action is also called derivative control because it uses the derivative of the function as part of the input.

ELECTRIC AND ELECTRONIC CONTROLLERS

The majority of electric or electronic controllers have a dc output and a range of 5:1 between maximum and minimum signals. The input can be alternating current from a magnetic transducer or direct current from a resistive, thermoelectric, or piezoelectric transducer. Within the controller, the error or deviation is measured either by voltage comparison or by force comparison.

Comparison of ac voltage signals can be accomplished as shown in Fig. 46*a*. The process variable is sensed by a differential transformer. The set-point signal is provided by the output of another differential transformer. A controller measures the error between the two.

In direct-current voltage comparison, Fig. 46*b*, the process variable creates a dc voltage output which is compared to a dc voltage from a constant-voltage source. The controller measures any difference between the two voltage signals.

Force comparison is used in a controller for comparison of transducer-current output and set-point current, Fig. 47*a*.

ELECTRIC AND ELECTRONIC CONTROLLERS

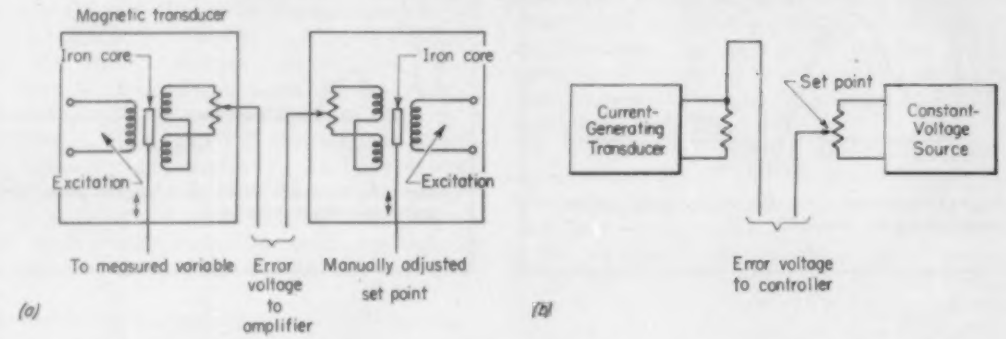


Fig. 46—Typical systems for comparison of ac voltages, *a*, and for dc voltages, *b*.

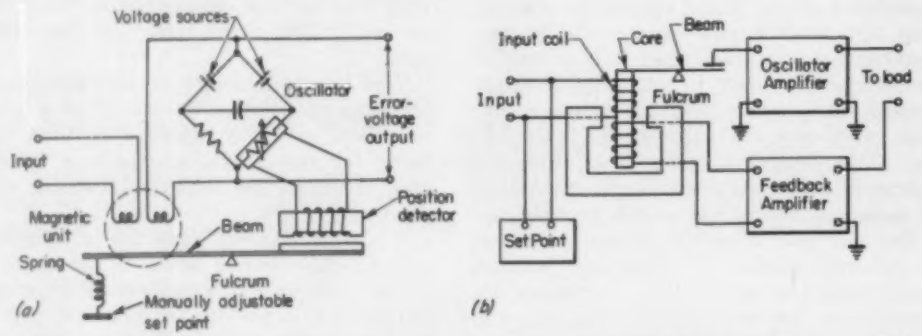


Fig. 47—Force-comparison systems for comparing transducer current with a balancing current. In *a*, the set-point force is provided by an adjustable spring. (Courtesy, Minneapolis-Honeywell Regulator Co.) In *b*, set-point force is provided by an adjustable current acting through a coil. (Courtesy, Robertshaw-Fulton Controls Co.)

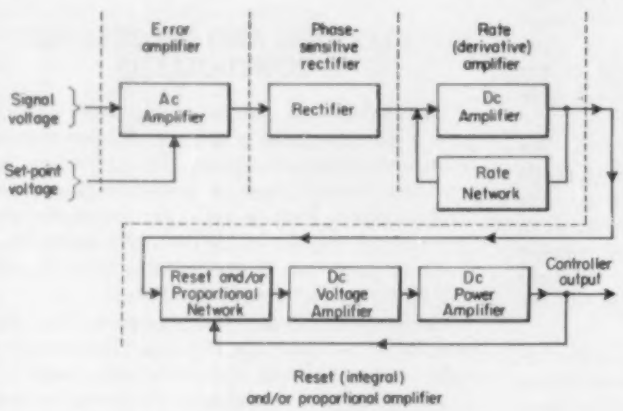


Fig. 48—Relationship of the four major sections of one type of electronic controller. (Courtesy, The Crane Co., Swartwout Div.)

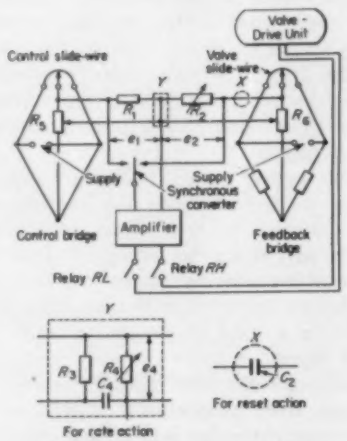


Fig. 49—Proportional, reset, and rate-action electronic controller for positioning a valve in a process system. (Courtesy, Leeds & Northrup Co.)

The set-point force is a calibrated spring which acts on a beam. Two separate coils, one for input-signal current and one for balancing current, also develop forces. Beam balance is noted by a position-detector, which adjusts an oscillator amplifier to give a voltage output proportional to the magnitude and direction of the process deviation.

In another force-comparison system, Fig. 47*b*, the

set point is an adjustable current, and the measured signal is a current. Both currents come from high-impedance sources which are differentially connected across a low-impedance coil. This coil acts on the beam to create a deflection proportional to the controlled variable. The deflection causes the oscillator-amplifier output current to vary. This current signals the actuator and also energizes a second coil to balance the beam.

A fully electronic controller incorporating all the features described for automatic units is shown in Fig. 48. It is a complete package consisting of four plug-in units. The controller is designed to receive an input signal of zero to 0.500 v at 60 cps. If a transducer with a dc output is used, a dc to ac converter is required. The controller produces an output signal of 1 to 5 ma dc with a 12,000-ohm load. The proportional band is adjustable from 2.6 to 200 per cent in 12 steps. The standard reset action is 0.1 to 380 repeats per min. Other proportional bands and reset times are also available.

The error amplifier compares the voltage produced by the sensing element with a voltage produced by the set point or control point. If the two signals are equal, the output of the error amplifier is zero, and the system is in control and is satisfied with the output level of the controller. If an error signal develops, it is amplified by a factor of 240 and applied to the input of the phase-sensitive rectifier.

The phase-sensitive rectifier has two functions: 1. To convert the ac output of the error amplifier into direct current. 2. To determine in which direction the corrective action of the controller must be applied. If there is no error signal, no corrective action is required. If the sensing-element signal is greater than the set-point signal, the output of the phase-sensitive rectifier changes in one direction. If the sensing-element signal is less than the set-point signal, the output changes in the opposite direction. Thus, the rectifier must be phase-sensitive. The output of the rectifier is a dc voltage that is proportional to the amount of error and of such polarity as to correct the error.

When the rate switch in the controller is in the *off* position, the rate-amplifier output is equal to its input. This voltage gain of one is obtained within the dc amplifier by negative feedback of the output to the input. Otherwise, the amplifiers would normally have high gain.

When rate action is switched into the circuit, the output from the dc amplifier is fed back to the input through the rate network, which temporarily delays the feedback. A sudden change in voltage at the input to the rate amplifier results in high amplification until the signal, delayed by the rate network, gets back to the input to reduce the amplifier gain to unity. Thus, the rate network causes the dc amplifier output to vary in proportion to both the magnitude and the rate of change of the error signal.

When only the proportional network is used, the signal fed into the dc voltage amplifier is a ratio, or proportion, between the signal from the rate amplifier and the controller output. This ratio is adjustable so that the error signal must vary over either a wide band or a narrow band to give a 100 per cent change in controller output.

When the reset-plus-proportional network is used, the amplifier provides a high degree of amplification for steady state or extremely slow changes in input. If the input signal changes rapidly—for example, because of pulsations in the system—the output of the controller is fed back into the input of the dc voltage amplifier through the reset network, thus, reducing the amplification of the output section.

This combination of high amplification and transient feedback provides the controller with an initially wide proportional band for rapid input-amplitude changes. However, because of the characteristics of the reset network, the wide proportional band slowly reduces to a narrow proportional band. Under these conditions, proportional-band control is still effective since it controls the amplitude of the input to the dc voltage amplifier. The proportional action is electrically independent of the reset action, and vice versa, although the two are mechanically intermixed. The control circuit of another electronic controller offering proportional, reset, and rate action is shown in Fig. 49. Two Wheatstone bridges are connected to a detecting amplifier. Circuit *Y* is a resistance-capacitance network for the addition of rate action. Circuit *X* is a capacitor for the addition of reset action. For proportional action only, these two circuits are not included in the controller. R_5 and R_6 are proportional-band rheostats for adjusting the percentage of recorder/indicator range over which the valve travels in moving from full-open to full-closed positions.

Proportional action is accomplished as follows: When the process is at set point, the control and feedback bridges are balanced, and voltages e_1 and e_2 are at zero. As the process variable changes, the control slide-wire moves proportionally and produces an unbalanced voltage, e_1, across resistor R_1. The voltage difference between e_1 and e_2 is detected by the amplifier. The output from the amplifier closes either relay *RL* or relay *RH*, depending on whether e_1 is higher or lower than e_2.

One relay operates the valve-drive unit in one direction; the other relay operates the valve-drive unit in the opposite direction. Because the valve-drive unit is mechanically coupled to the valve slide-wire, the valve slide-wire unbalances the feedback bridge until e_2 equals e_1. When e_1 and e_2 are again equal, relay *RL*, or *RH*, opens and stops the valve-drive unit. The change in the position of the valve varies the input to the process to return the process to the set point. If the input to the process is too much or too little, the process variable will again position the control slide-wire to return the process to the set point.

If there is a sustained load change in the process, proportional control alone may not return the process to the set point. In this case, reset action is added (circuit *X*). The speed of reset is adjusted by means of resistor R_2. If the process lags above or below the set point, a voltage is produced at e_1 other than zero. To bring e_2 equal to e_1, a current flows through

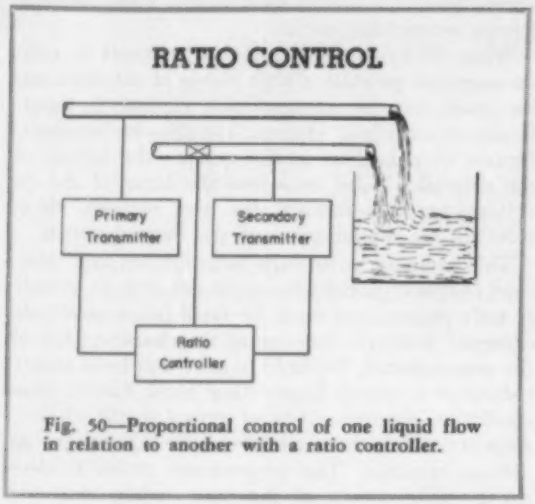


Fig. 50—Proportional control of one liquid flow in relation to another with a ratio controller.

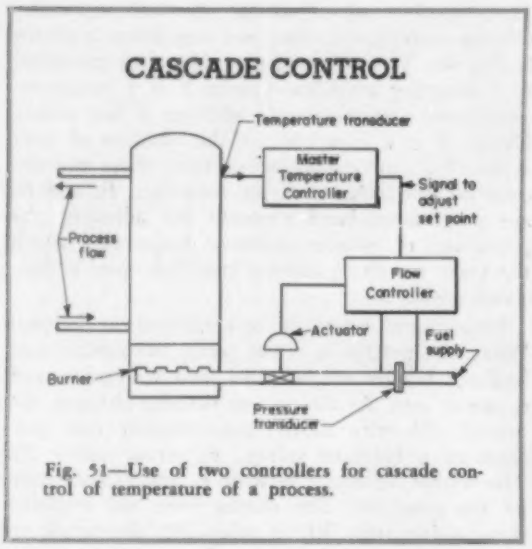


Fig. 51—Use of two controllers for cascade control of temperature of a process.

R_2 and charges capacitor C_2. As C_2 charges, current flow in the feedback bridge diminishes. Because e_1 and e_2 are still unbalanced, the valve-drive unit continues to operate until e_1 returns to zero and the process returns to the set point.

When rapid changes in a process variable cannot be corrected quickly enough by proportional action alone, rate action provided by circuit Y is added to the control system. The rate time is adjusted by means of resistor R_4. As the control slide-wire moves, it produces a changing voltage across R_1 and R_3. As long as the voltage across R_3 continues to change, current flows through R_1 and R_4, charging capacitor C_4. Rate action, therefore, produces rate voltage e_4.

Voltage e_4 adds to the proportional voltage across R_1 and thus makes voltage e_1 greater than it would be with proportional action alone. To make e_2 equal to e_1, the voltage drop produced by e_4 across R_2 must be overcome. This can be done only by continued operation of the valve-drive unit and valve slide-wire until the process is returned to the set point.

Adjustment of the valve by means of rate action is continued as long as the control slide-wire is moving. As soon as the control slide-wire comes to rest, there is no changing voltage across R_3, capacitor C_4 ceases to be charged, and no added voltage at e_4 must be overcome.

RATIO CONTROL

Controllers are often modified so that two signals can influence the final operation of one actuator. A preset ratio in the ratio controller shown in Fig. 50 measures and compares transmitted signals from two flows and adjusts the actuator to control the secondary flow in proportion to variations in the primary flow. Ratio control can be applied to control several flows, providing each secondary flow is proportional to the primary.

CASCADE CONTROL

The use of two controllers on a process system constitutes cascade control. Each controller governs a separate function of the process, but the two "in cascade" control the final process. For example, to control the temperature of a particular process, a temperature transducer, a master controller, and an actuator are connected to the process. As temperature rises, the controller closes the actuator, shutting down the flow of fuel to the heat source. As the temperature falls, the controller opens the actuator, allowing more fuel to flow to the heat source.

If the pressure of the fuel entering the process rises or falls, a second variable is introduced. This variable can cause a lag or overshoot which is not corrected until the transducer senses the temperature variation in the process.

To permit closer control of the final process, a second controller is installed to control the variations in fuel pressure, Fig. 51. The master controller senses temperature variation and transmits a signal which adjusts the set point of the flow controller. The flow controller operates the actuator in the fuel line in accordance with pressure variations in the fuel line and the temperature-controlled set point. The master controller signal is thus "cascaded" to the flow controller for closer control of the process.

A short-cut design procedure for

Springs for Cam Followers

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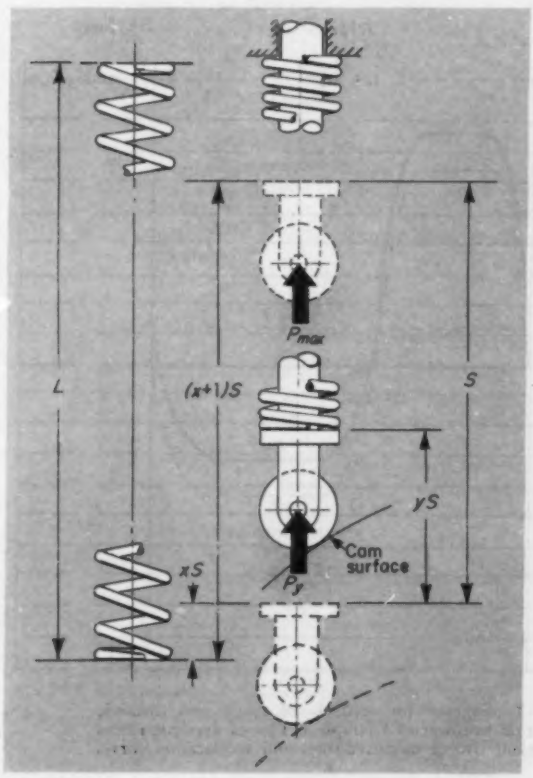
IN high-speed cam-follower systems, two methods are commonly used to maintain contact of the follower with the cam profile: 1. Conjugate cams. 2. Springs.

Fig. 1—Typical compression spring and cam follower assembly.



Conjugate-cam and follower arrangements offer certain advantages from a kinematic view, but are expensive. Where it can be used, the less costly combination of a simple plate cam and a spring-loaded follower is preferred.

Follower springs are generally of the helical compression type, Fig. 1, to take advantage of the full strength of the spring material. Extension springs have stress concentrations at the hooks, limiting the practical stress levels that can be achieved.

In service, these springs usually must be able to withstand severe cyclic loading conditions over an extended period of time. If the spring is too weak, fatigue failure is likely. If the spring is too strong, excessive wear of follower and cam will result.

To speed and simplify design of round-wire compression springs to satisfy such requirements, this article presents a short-cut technique that bypasses the time-consuming trial-and-error procedures of conventional methods. Once maximum-load and allowable-stress levels are established, a range of suitable wire sizes can be quickly determined for selection of optimum spring proportions. Calculations are based on a preselected maximum stress of conservative value to prevent gradual decrease of spring pressure in service. Although attention is focused here on the specific requirements of cam-follower systems, the method may be readily adapted for use with other recurring spring design problems.

Load Analysis: First step in follower-spring design is to determine the design load, P_{max}. Magnitude of this load depends on the maximum resisting force—friction and work plus dynamic (inertia)—developed by the system, and on the spring deflection at that condition.

For accurate analysis of system forces, an $F + Y$

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diagram, Fig. 2, can be constructed. In this diagram, force F (friction and work) and dynamic force Y are plotted separately. Forces which press the follower against the cam surface are plotted above a neutral line; separating forces are plotted below the line.

The algebraic sum of these forces, $F + Y$, then may be readily determined graphically, and plotted, to find the magnitude and position of the largest combined force, P_y. This position, expressed in terms of stroke S, is yS. Here, stroke S is measured from the "lowest" position of the follower on the cam where the initial deflection of the spring, expressed in terms of the stroke, is xS.

Since spring force is proportional to deflection,

$$\frac{P_{max}}{P_y} = \frac{xS + S}{xS + yS}$$

which gives

$$P_{max} = \frac{x + 1}{x + y} P_y \qquad (1)$$

To provide a margin of safety, the spring should be capable of handling a greater force than that given by Equation 1. Thus, a more realistic expression for design purposes is:

$$P_{max} \geqq 1.2 \frac{x + 1}{x + y} P_y \qquad (2)$$

If a force analysis with an $F + Y$ diagram is impractical or inconvenient an alternative approach is to assume that the largest combined force, $P_y = F + Y$, occurs at the middle of the stroke. Thus, $y = 0.5$, and

$$P_{max} \geqq 1.2 \frac{x + 1}{x + 0.5} (F + Y) \geqq 1.2 \frac{x + 1}{x + 0.5} P_y \qquad (3)$$

where F is the estimated sum of frictional and work-load resistances, and Y is the calculated maximum dynamic (inertial) load acting in the same direction. Usually, greatest negative force exists when the

Table 1—Effect of x on Spring Loads

x	$\frac{x+1}{x+0.5}$	$\frac{P_{max} - P_y}{P_y}$ (per cent)	$\frac{x+1}{x}$	$\frac{P_{max} - P_{min}}{P_{min}}$ (per cent)
0.5	1.500	50.0	3.000	200
1.0	1.333	33.3	2.000	100
1.5	1.250	25.0	1.667	66.7
2.0	1.200	20.0	1.500	50.0
2.5	1.167	16.7	1.400	40.0
3	1.143	14.3	1.333	33.3
4	1.111	11.1	1.250	25.0
5	1.091	9.1	1.200	20.0
6	1.077	7.7	1.167	16.7

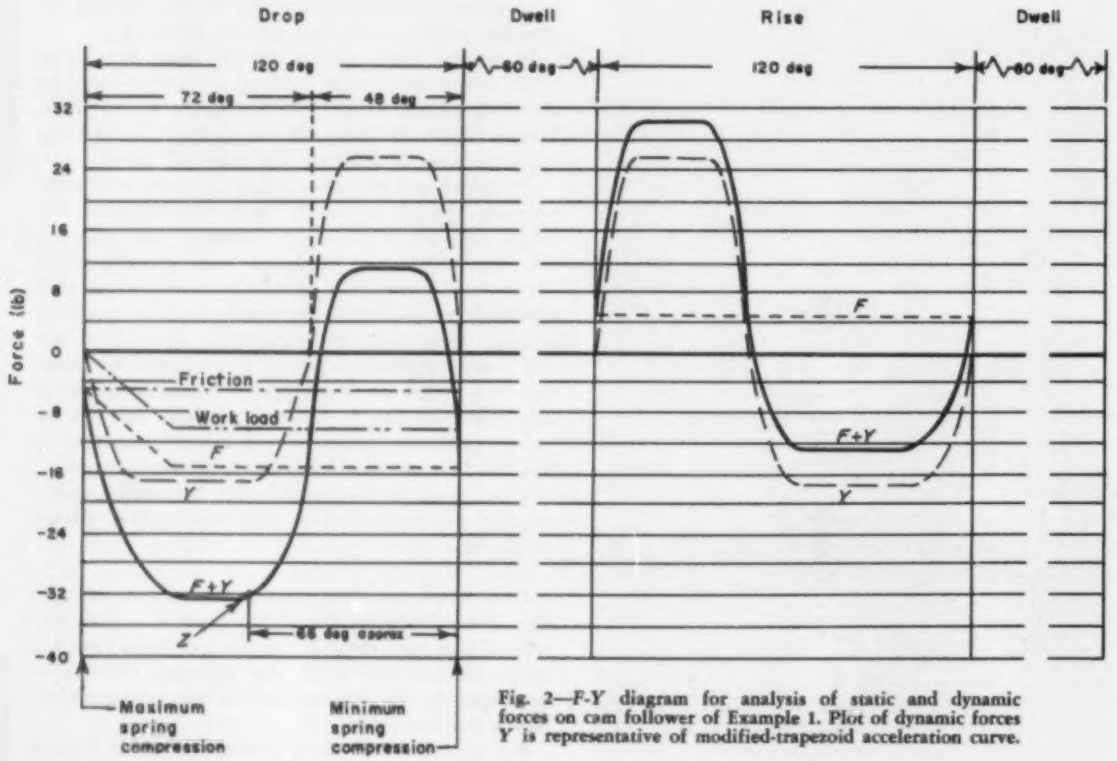


Fig. 2—F-Y diagram for analysis of static and dynamic forces on cam follower of Example 1. Plot of dynamic forces Y is representative of modified-trapezoid acceleration curve.

follower moves from max to min cam radius.

One of the first problems in design is to select a value of x. Influence of this parameter on load relationships is shown by Table 1. Data in the second and third columns are based on a maximum force condition at the midstroke position where

$$\frac{P_{max}}{P_y} = \frac{x+1}{x+0.5}$$

As these results indicate, a small value of x increases the spring force excessively when the follower rides on the maximum radius of the cam.

The last two columns of Table 1 represent the total variation of spring force when spring deflection changes from xS to $(x + 1)S$, giving

$$\frac{P_{max}}{P_{min}} = \frac{x+1}{x}$$

If friction and work forces F are high near minimum cam radius as the follower moves "downward," small values of x should be avoided. A large value of P_{max} may result if $x < 2$.

Nomenclature

C = Spring index
= D/d
C_A, C_D = Coefficients of maximum follower acceleration and maximum follower deceleration, respectively
D, D_i, D_o = Mean diameter, ID, and OD, respectively, of spring, in.
d = Wire diameter, in.
e = Deflection from minimum working height to solid height of spring, in.
F = Maximum friction and work force to be overcome by spring, lb
G = Torsional modulus of rigidity of spring material, psi
K = Wahl stress correction factor
L = Free length of spring, in.
N = Cam speed, rps
n = Number of active spring coils
P_{max} = Load at minimum compressed height of spring, lb
P_y = Maximum load imposed on spring by cam follower, lb
p = Ratio of deceleration period to acceleration period of cam follower
q = Pitch of spring, in.
S = Stroke of spring per revolution of cam, in.
U = Spring size factor
= CK/d^2
T = Working period of cam cycle, sec
t = Time for one cycle of free vibration of spring, sec
W = Effective weight of cam follower system supported by spring, lb
x = Ratio of initial spring deflection to spring stroke
Y = Maximum dynamic force to be overcome by spring, lb
y = Ratio of follower displacement at any point to follower stroke
α = Angular displacement of cam during working stroke, deg
Δ, Δ_{max} = Spring deflection at working height and solid height, respectively, in.
δ = Deflection per coil of spring, in.
Σ = Elastic limit of spring material in torsion, psi
σ, σ_{max} = Working-load and solid-height stress, respectively, of spring, psi

Design Procedure: Basic design equations for helical, round-wire compression springs are:

STRESS,

$$\sigma = \frac{8 P_{max} DK}{\pi d^3} = \frac{8 P_{max} CK}{\pi d^2} \quad (4)$$

DEFLECTION PER COIL,

$$\delta = \frac{8 P_{max} D^3}{G d^4} = \frac{8 P_{max} C^3}{G d} \quad (5)$$

DEFLECTION AT WORKING LOAD,

$$\Delta = \delta n = S(x+1) \quad (6)$$

DEFLECTION AT SOLID HEIGHT,

$$\Delta_{max} = S(x+1) + e \quad (7)$$

PITCH,

$$q = \frac{\Delta_{max}}{n} + d \quad (8)$$

FREE LENGTH (SQUARED AND GROUND ENDS),

$$L = qn + 2d = \Delta_{max} + (n+2)d \quad (9)$$

OUTSIDE DIAMETER,

$$D_o = D + d \quad (10)$$

INSIDE DIAMETER,

$$D_i = D - d \quad (11)$$

NUMBER OF ACTIVE COILS,

$$n = \frac{\Delta}{\delta} = \frac{S(x+1)Gd}{8 P_{max} C^3} \quad (12)$$

WAHL CORRECTION FACTOR

$$K = \frac{4C-1}{4C-4} + \frac{0.615}{C} \quad (13)$$

Steps of the complete design procedure are:

1. Determine P_y by one of the methods previously outlined.

2. Select value of x.

3. Calculate P_{max} from Equation 2 or 3.

4. Determine maximum allowable working stress σ. This stress value can be calculated directly from the elastic limit, Σ, of the spring material selected. To prevent fatigue failure under the service conditions normally associated with high-speed cam-follower systems, make $\sigma = 0.4\ \Sigma$ to $0.5\ \Sigma$.

5. Calculate U from

$$U = \frac{CK}{d^2} = \frac{\pi \sigma}{8 P_{max}} \quad (14)$$

6. Find suitable wire sizes d using charts in Fig. 3. These charts provide plots of d versus U for spring indexes C from 2 to 20. Fig. 3*a* covers the range from $U = 10$ to 1000, Fig. 3*b* from $U = 1000$ to 20,000. To use these charts, draw a horizontal line at

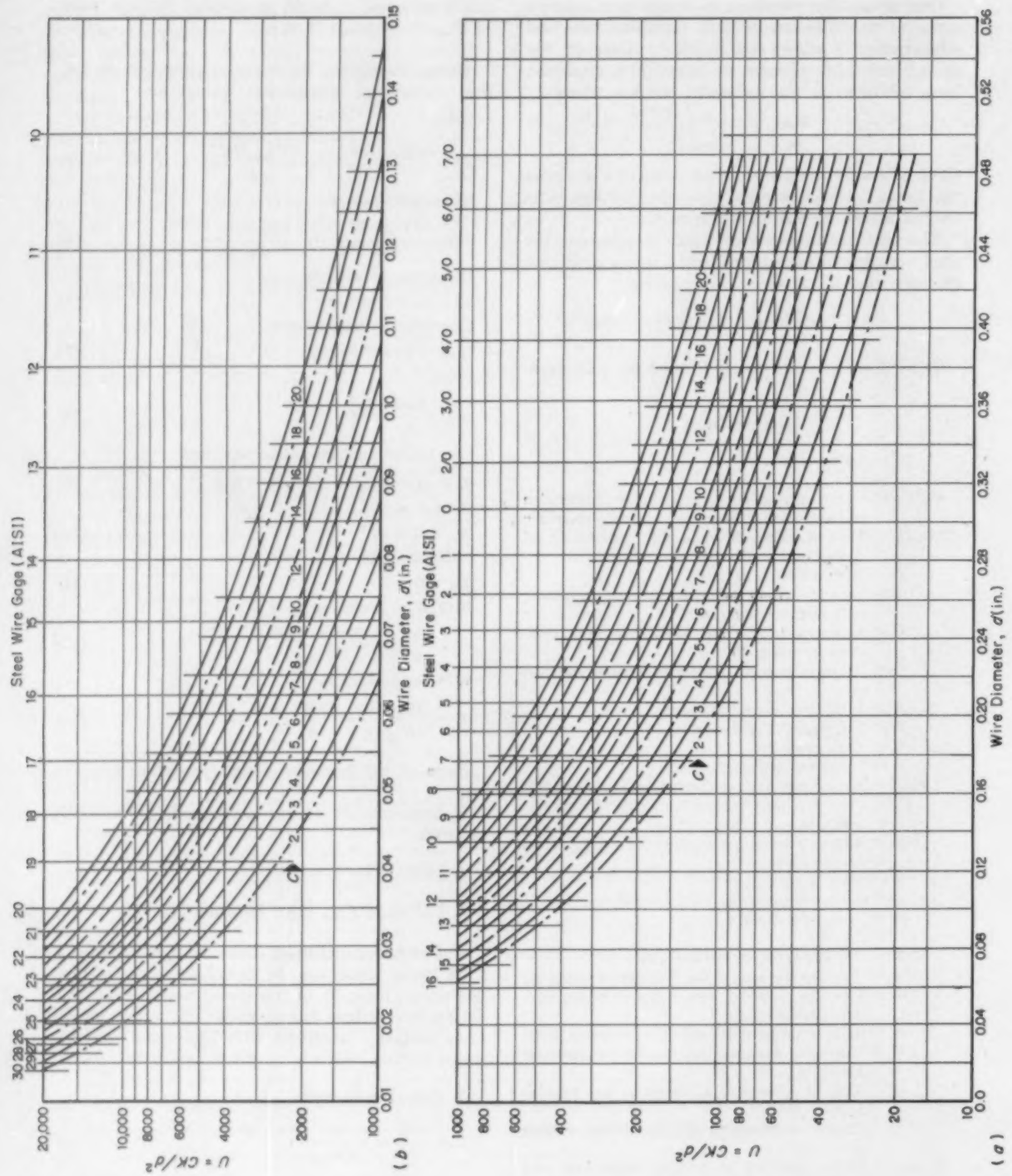


Fig. 3—Charts for determination of standard wire sizes and corresponding spring indexes that satisfy load-stress requirements. Chart at *a* covers range from $U = 10$ to 1000, chart at *b* from $U = 1000$ to 20,000. Steel Wire Gage numbers given here are the same as those for the Washburn and Moen gage.

the calculated value of U. Intersections of this line with the C-plots define the range of wire sizes that satisfy stress requirements at values of C between 2 and 20. Standard wire sizes in this range, and corresponding approximate values of C, may be read directly from the chart at the intersections of the horizontal line with the Steel Wire Gage lines.

From these chart data, selection may be quickly narrowed to a few choices by using Equations 10 and 11 (where $D = Cd$) to find those wire diameters that give a suitable coil size, D_o or D_i. Further calculations, to determine a final choice, can then be confined to these few selections.

7. Calculate exact value of spring index C for each selected wire size from

$$C = 0.5 \left\{ U d^2 - 0.365 + [(U d^2)^2 + 2.593 - 4.73\, U d^2]^{1/2} \right\} \quad (15)$$

If the corresponding values of D_o or D_i are not satisfactory, this value of C may be adjusted slightly without altering the wire size. Keep in mind, however, that an increase in C will have these effects:

- Stress σ will increase in direct proportion to C (Equation 4).
- Number of active coils n will decrease in inverse proportion to C^3 (Equation 12).
- Deflection per coil δ will increase in direct proportion to C^3 (Equation 5).

8. Calculate number of active coils n from Equation 12.

9. Calculate total deflection (to solid height) Δ_{max} from Equation 7. First step in this calculation is to select a value of e. If loads P_y and P_{max} are accurate values and are not likely to change, the value of e can be small, say $e = 1/4$ to $1/2$ in. But if there is a possibility that P_y may have been underestimated, or that the cam-follower system will be operated above design speed, then a larger value of e should be used to provide a greater range of possible variation in spring force.

10. Calculate spring pitch q from Equation 8.

11. Calculate free length L from Equation 9.

12. Check solid-height stress. Since stress is proportional to load which, in turn, is proportional to deflection,

$$\sigma_{max} = \frac{S(x+1)+e}{S(x+1)}\,\sigma \quad (16)$$

If $e = S$ and $x = 3$, $\sigma_{max} = 1.25\sigma$.

13. Check vibration characteristics of spring. The ratio, T/t, represents the number of free vibrations of the spring during the period in which spring force varies between a minimum and a maximum. For steel springs, a close approximation is

$$\frac{T}{t} = 230\,\frac{a}{NnCD} \quad (17)$$

This ratio always should be as large as possible and never under 2.5.

Example 1: Design a compression spring for a cam-follower system which positions a part in a holding fixture. The work stroke occurs during the "drop" when the follower moves from maximum to minimum cam radius. The cam controls the kinematics of the stroke but the work is done by the spring. This arrangement is commonly used to avoid a serious jam when there is a chance that a part may not enter the opening in the holding fixture.

DESIGN DATA: Stroke of the cam follower is 2 in. Cam events for the full cycle are: Working stroke (drop), 120 deg; dwell, 60 deg; return stroke (rise), 120 deg; dwell, 60 deg. Cam speed is 180 rpm, or $N = 3$ rps.

The compression spring acts directly on the cam follower. Thus, the weight of the follower assembly is concentrated at the follower. Also, stroke of the spring $S = 2$ in.

Weight of the follower assembly is $W = 10$ lb. Frictional resistance is estimated as 5 lb. Work resistance during the drop reaches a maximum value of 10 lb.

The acceleration diagram is of modified-trapezoid form with factor $b = 0.25$.* To reduce spring loads, the acceleration period during the drop is made 50 per cent longer than the deceleration period ($p = 2/3$). During the rise, the deceleration period is longer ($p = 1.5$). Thus, the maximum acceleration coefficient, C_A, for the drop and the maximum deceleration coefficient, C_D, for the rise are equal: $C_A = C_D = 4.08$. Similarly, C_D (drop) = C_A (rise) = 6.12.

SOLUTION: Maximum dynamic forces may be calculated from

$$Y = C_A S \left(\frac{360\,N}{\alpha}\right)^2 \frac{W}{386}$$

$$Y = C_D S \left(\frac{360\,N}{\alpha}\right)^2 \frac{W}{386}$$

For $C_A = C_D = 4.08$, $Y = 17.2$ lb. For $C_A = C_D = 6.12$, $Y = 25.7$ lb.

The $F + Y$ diagram for this cam-follower system is shown in Fig. 2. From the previous data, $F_{max} = 5 + 10 = 15$ lb. Largest force separating the follower and cam is: $P_y = (F + Y)_{max} = 15 + 17.2 = 32.2$ lb. In Fig. 2, point Z in the drop region of the $F + Y$ plot is the critical condition for the spring. From displacement tables, the follower position corresponding to point Z is 0.68 S above the lowest position. Thus, $y = 0.68$.

This analysis illustrates the graphical technique discussed earlier. Next step is to determine P_{max}. Equation 2 would appear to be in order for this calculation. However, in this instance, the more practical approach is to use Equation 3 which is

*C. N. Neklutin—"Trig-Type Cam Profiles," MACHINE DESIGN, Vol. 31, No. 21, October 15, 1959, pp. 175-187.

Table 2—Example Calculations

Item	Example 1			Example 2		
P_y (lb)		32.2			....	
x		3			2	
P_{max} (lb)		44			250	
σ (psi)		60,000			51,000	
U, Equation 14		530			80	
d (gage), Fig. 3	11	10	9	0	2/0	3/0
d (in.)	0.120	0.135	0.148	0.307	0.331	0.363
C, Fig. 3	6.2	8.2	10.2	6	7.3	9.1
D (in.)	0.744	1.107	1.510	1.842	2.416	3.302
C, Equation 15	6.12	8.19	10.2	6.03	7.29	9.08
D (in.)	0.734	1.106	1.504	1.851	2.413	3.295
D_o (in.), Equation 10	0.854	1.241	1.652	2.158	2.744	3.658
D_i (in.), Equation 11	0.614	0.971	1.356	1.544	2.082	2.932
n, Equation 12	137	64	37	48	29.5	16.7
e (in.)	0.5	0.5	0.5	1	1	1
Δ_{max}, Equation 7	8.5	0.8	8.5	7	7	7
q (in.), Equation 8	0.182	0.268	0.378	0.453	0.568	0.781
L (in.), Equation 9	25.18	17.41	14.27	22.35	14.47	13.07
σ_{max} (psi), Equation 16	63,750	63,750	63,750	59,500	59,500	59,500
T/t, Equation 17	15	16	16.3	25.7	26.6	27.8

based on $y = 0.5$. The result is a slightly greater safety factor, and a simplified calculation job.

To minimize variation of spring force, let $x = 3$. From Equation 3, then,

$$P_{max} = 1.2(32.2)\frac{(3+1)}{(3+0.5)} = 44 \text{ lb}$$

Assume the spring material has an elastic limit, $E = 120{,}000$ psi. Maximum allowable working stress is $\sigma = 0.5\ (120{,}000) = 60{,}000$ psi.

From Equation 14, $U = 3.14\ (60{,}000)/[8(44)] = 535$. Use $U = 530$.

From Fig. 3*a* at $U = 530$, suitable wire sizes range from No. 13 through No. 6 gage. Assume here that only three of these wire sizes—No. 9, 10, and 11—give coil diameters, D, that fit design requirements.

Complete calculations for these wire sizes are summarized in Table 2. These calculated dimensions can be adjusted slightly to suit dimensional requirements. Then, by cross comparison of these tabulated data with design requirements, the best spring for the job can be selected.

Example 2: Design a compression spring to hold the ram of a punch press firmly against the connecting rod to prevent knocks. Two sets of forces tend to separate the bearing surfaces of the ram and the connecting rod: 1. Weight of ram and friction in guides; 2. Deceleration during the downward stroke and acceleration during the upward stroke, assuming the separation of dies does not create any noticeable resistance.

DESIGN DATA: Weight of the ram is 50 lb and estimated frictional resistance in the guides is 9 lb. Speed of the crankshaft is 300 rpm, or $N = 5$ rps. Ram stroke is 2 in.

SOLUTION: Maximum acceleration A (or deceleration) of a very long connecting rod with a stroke, S_r, is

$$A = \frac{\pi^2 S_r}{2}\left(\frac{360}{180}N\right)^2$$

$$= \frac{\pi^2 2}{2}[2(5)]^2 = 983 \text{ in./sec/sec}$$

which gives in terms of gravity units, $A = 983/386 = 2.56g$. Therefore, corresponding dynamic force is $Y_A = 2.56\ (50) = 128$ lb.

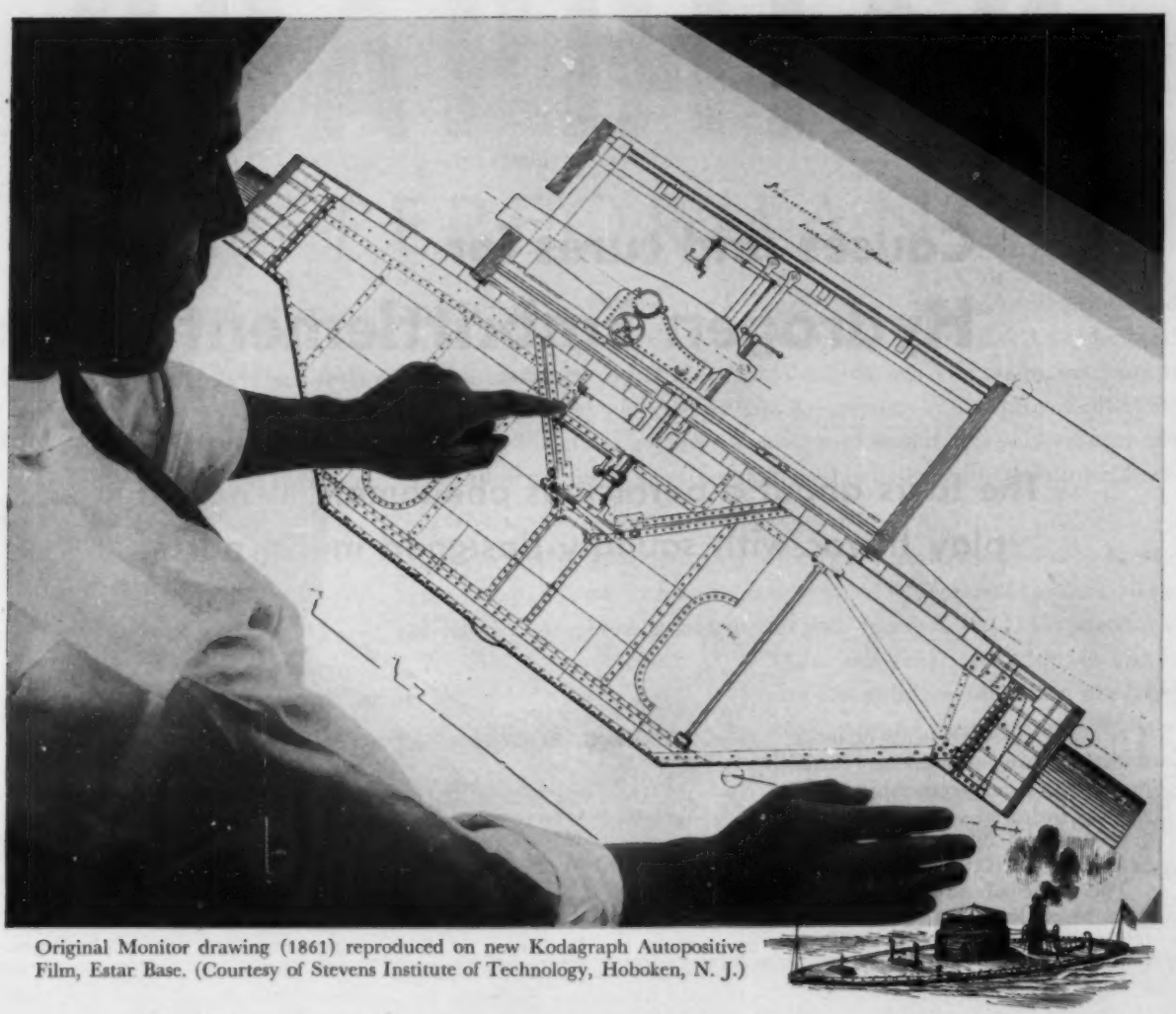
If, as assumed here, the ratio of connecting rod length to crank radius is 10, the acceleration at the lowest position of the ram will be 10 per cent greater than the value given by the previous equation. Thus, maximum dynamic force, $Y_{max} = 128 + 13 = 141$ lb, and total maximum separating force, $P_y = 141 + 50 + 9 = 200$ lb.

Based on a safety factor of 1.25, $P_{max} = 1.25\ (200) = 250$ lb. Maximum acceleration occurs at the start of the upward stroke when the spring is fully compressed. Select $x = 2$. From Equation 6, $\Delta = 2\ (2 + 1) = 6$ in.

Solid height of the spring is reached when $e = 1$ in. From Equation 7, $\Delta_{max} = 6 + 1 = 7$ in. Let maximum working stress $\sigma = 51{,}000$ psi. From Equation 14 then, $U = 3.14\ (51{,}000)/[8\ (250)] = 80$

From Fig. 3*a* at $U = 80$, suitable wire sizes range from No. 3 to 7/0 gage. Assume here that only three sizes—No. 0, 2/0, and 3/0—satisfy coil diameter requirements.

Remaining calculations are completed in the same manner as for Example 1. Results of these calculations are summarized in Table 2.



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Causes and cures for Hydrogen Embrittlement

The facts about a pernicious phenomenon that can play havoc with soundly-designed metal parts

HARRY C. ROGERS
Metallurgist
Alloy Studies Section
Research Laboratory
General Electric Co.
Schenectady, N. Y.

IN metal parts, particularly those used for structural service, a little hydrogen is a dangerous thing. Only a little hydrogen is often all that is needed to produce a serious metal failure.

The principal structural metals with which hydrogen is a problem fall into two major categories: "Exothermic occluders" and "endothermic occluders." The former are characterized by the large quantities of hydrogen absorbed, the tendency to form definite hydrides, and the negative heat of solution which results in a solubility decrease with increasing temperature at constant pressure. Exothermic occluders include vanadium, titanium, zirconium, tantalum, thorium, and cerium. Conversely, endothermic occluders, such as iron, copper, cobalt, and nickel, have lower hydrogen solubility which increases as the temperature is raised.

It is known, from thermodynamics, that gaseous hydrogen is composed primarily of molecular hydrogen with a very small percentage of atomic hydrogen in equilibrium. This amount increases both with temperature and pressure to the point where there is a significant absorption of hydrogen during heat treatment of iron and steel in an atmosphere containing hydrogen. In many instances hydrogen is picked up, not in the fabrication of the structure, but during its use. Hydrogen may be picked up from hot hydrogenous gases, particularly in pressure vessels, or it may be the result of a corrosion reaction which produces atomic hydrogen at the surface of the metal.

There appear to be four distinct ways in which hydrogen may embrittle metallic structures, or at least cause some damage to the structure which may increase its susceptibility to other forms of embrittlement. The approach to a solution of each problem is different.

Hydrogen Attack: This term has been applied to a permanent type of embrittlement that is the result of a chemical reaction of hydrogen with a second phase or a high local concentration of a minor element. The commercial materials in which this has been recognized as a severe problem are silver, copper, low-carbon iron, and steel. In the first three materials, the element with which the hydrogen reacts is oxygen. The formation of water vapor and the resulting oxygen depletion in the metal results in an intergranular embrittlement which cannot be eliminated by removing the hydrogen from the metal.

The principal source of hydrogen attack in steel has been the high-temperature reaction of hydrogen with the carbides in the steel to form methane. The structure then becomes weak and spongy with considerable permanent loss in ductility. Although increased pressure increases the rate of hydrogen attack in steel, it is unlikely that it will take place at any pressure below about 400 F.

Prevention is the only solution to this problem. Either one must use a material which is not susceptible to this form of attack—such as austenitic stainless steels or, in the case of copper, oxygen-free copper—or care must be taken to prevent exposure to hydrogen-producing atmosphere.

Hydride Embrittlement: A second form of embrittlement which plagues many exothermic occluders is hydride, or impact, embrittlement. Titanium and its alloys are outstanding examples. This form of embrittlement is characterized by an increasing tendency to brittleness with increasing hydrogen content,

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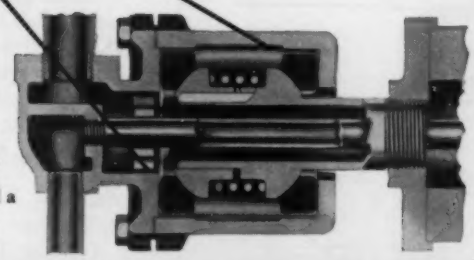

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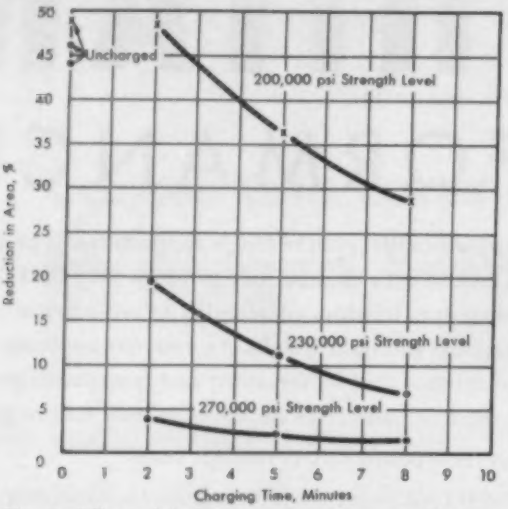

Fig. 1—Effect of hydrogen content (corresponding to charging time) on the ductility of AISI 4340 steel.

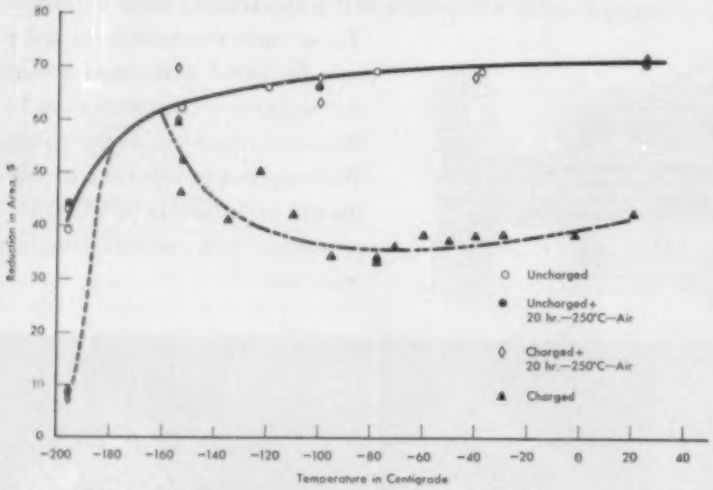

Fig. 2—Effect of temperature on the ductility of AISI 1020 steel in various conditions of charging and aging.

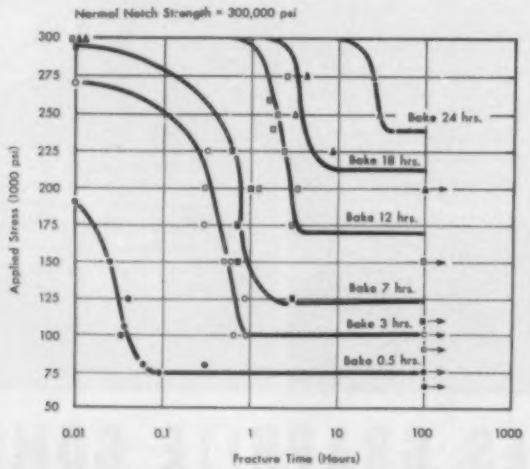

Fig. 3—Static fatigue for various hydrogen concentrations (baking times) in notched AISI 4340 steel at 230,000 psi.

decreasing temperature, and increasing strain rate, similar to the characteristics of the low-temperature brittleness in iron.

The metallurgical approach to a solution of this problem is either to heat-treat to produce a fine hydride precipitate or small grain size, or to increase the hydrogen tolerance by alloying.

True Hydrogen Embrittlement: This most investigated form of hydrogen embrittlement, known as "low strain rate embrittlement" in the titanium industry, occurs in iron and steel, titanium and its alloys, and vanadium. True hydrogen embrittlement is characterized primarily by the necessity for hydrogen to be present during the deformation and by a decreasing ductility with decreasing strain rate, which is contrary to the behavior in most other types of embrittlement.

There seems to be no embrittlement when iron and steel are tested above 350 to 400 F. The degree of embrittlement increases with increasing hydrogen content, as shown in Fig. 1. The same figure shows that the greater the strength level of the steel of a given composition and structure, the greater the sensitivity to hydrogen embrittlement.

One of the major problems in understanding this type of embrittlement is the difficulty in distinguishing between an effect of true hydrogen embrittlement, presumably recoverable on removal of the hydrogen, and permanent damage from the absorption of hydrogen. In tensile tests, Fig. 2, uncharged steel showed a gradual loss in ductility as temperature was lowered. The aging treatment had no effect on the ductility of uncharged steel at any temperature. Cathodically charged specimens, on the other hand, showed characteristic embrittlement in the neighborhood of room temperature, with ductility approaching that of uncharged specimens as the test temperature was lowered and reaching it at about −160 C. At liquid nitrogen temperature, ductility is again much lower than that of uncharged steel.

One conclusion is that recovery from true hydrogen embrittlement on aging is obscured by permanent damage associated with the takeup of hydrogen. This differentiation

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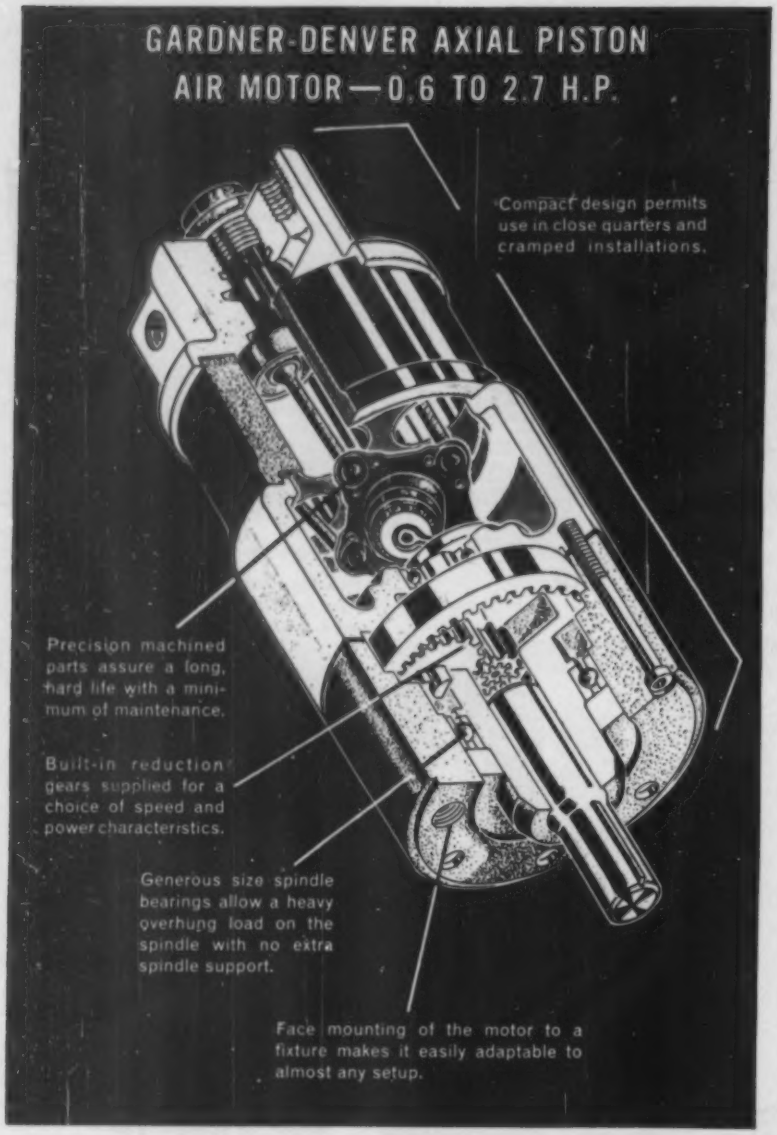
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becomes more difficult in the harder materials which are more sensitive to structural defects.

Cold work markedly increases the embrittlement on hydrogen charging and also decreases the ability of the metal to recover on aging. Also, there is a marked effect of crystal structure on this form of embrittlement.

Delayed Failure: The most spectacular of all the phenomena associated with true hydrogen embrittlement is delayed failure, also called static fatigue. General characteristics of this type failure are the low stresses at which it occurs and the long waiting period after stressing before the relatively brittle fracture takes place.

Two things stand out as most significant in this type of failure:

- Delayed failure can occur when the same material with the same hydrogen content shows no embrittlement in a tensile test.
- Stress that results in failure may be either applied or residual, such as transformation or quenching stress. Failure under the action of a residual stress appears to be spontaneous.

The general shape of the time for failure as a function of the stress level and hydrogen content for uniform distribution of hydrogen is shown in Fig. 3. The most important feature is that for every testing condition there exists a stress, called the static fatigue limit, below which failure does not occur even after an extensive waiting period. This stress decreases as notch severity increases, and is a relatively lower proportion of the uncharged notch tensile stress as the strength level in a particular steel increases.

When hydrogen distribution is highly nonuniform, the hydrogen-rich case cracks almost instantaneously on stressing and slow crack growth follows the inward diffusion of the hydrogen front. Hence, once the part has been stressed, there is some nonrecoverable damage. In both cases, if no stresses exceeding the static fatigue limit have been applied, and if the material contains no residual stresses which have had time to act since the piece contained hydrogen, the embrittlement should be recoverable.

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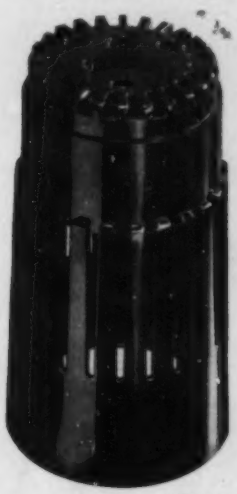

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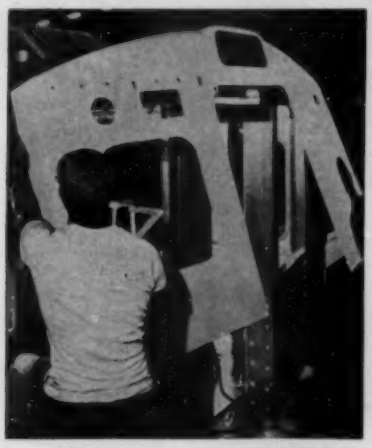

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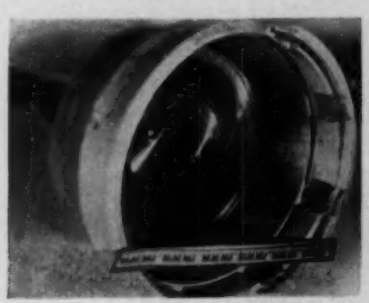

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- Easy-to-cast aluminum engine heads and intake manifolds, made in two sections bonded together with a leak-proof, heatproof seal.

We don't make these super-stickers ourselves. We merely supply the phenolic resins that give them many of the qualities a good structural adhesive must have, including permanent rigid set and heat resistance. If you'd like to know where you can get adhesives made with our resins, we'll be glad to tell you.

For more information on Durez materials mentioned above, check here:

- ☐ *Durez 13856 Black* phenolic molding compound (4-page bulletin)
- ☐ Hetron fire-retardant polyesters (designer's data file)
- ☐ "Durez Plastics News" (a review of current plastics applications, mailed bimonthly)

Check, clip and mail to us with your name, title, company address.

DUREZ PLASTICS DIVISION

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HOOKER CHEMICAL CORPORATION

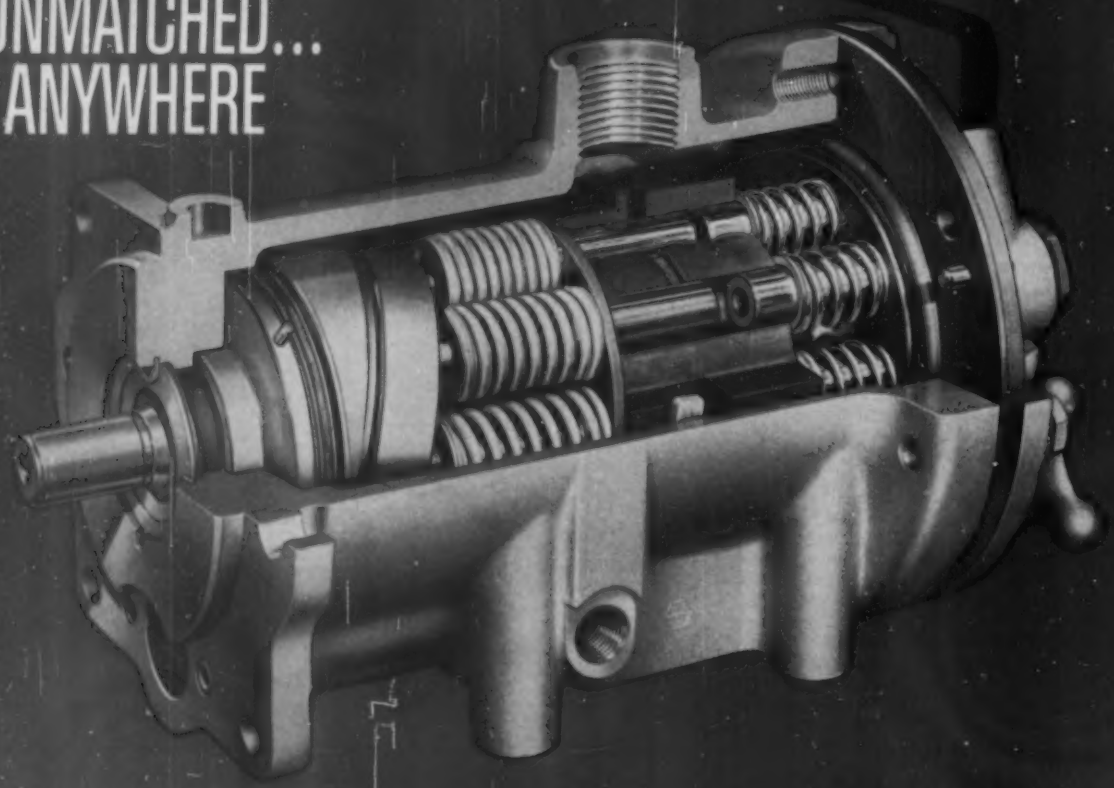
HOOKER CHEMICALS PLASTICS

Circle 299 on Page 19

WEATHERHEAD FLUID POWER PRODUCTS... SYSTEM ENGINEERED

NEW! WEATHERHEAD VARIABLE DISPLACEMENT HYDRAULIC PUMP

UNMATCHED... ANYWHERE



The new W07 pump gives economy and performance advantages unmatched in high pressure, fluid power system applications. No other mass-produced, variable displacement hydraulic pump can now offer all these benefits:

INSTANT RESPONSE... hydraulically balanced, direct cylinder stem actuation at lower power level without linkages.

HIGH EFFICIENCY... only two rotating parts; side loads on pistons minimized.

CONTROL VERSATILITY... pumping forces virtually eliminated from the displacement changing mechanism.

HIGH TEMPERATURE CAPABILITY... unique piston actuation permits fluids of low lubricity.

PUMP ECONOMY... size and weight are adaptable to a variety of applications; top reliability assured with no extensive fits.

Pressure compensation control is provided as standard and integral part of the pump in adjustable pressure ranges from 250 psi to 3000 psi.

The W07 pump incorporates J.I.C., S.A.E. and A.N.D. design requirements for industrial and mobile applications; meets stringent requirements of military specifications. Spline or keyway shafts are available.

Application and design data are available from your nearby Weatherhead sales engineer. Direct inquiries to:

THE WEATHERHEAD COMPANY
HYDRAULICS AND PNEUMATICS
300 EAST 131st STREET • CLEVELAND 8, OHIO

Circle 288 on Page 17

and suppliers of high-strength and high-hardness parts, such as springs and lock washers, for some time, but has now become even more severe with highly stressed high-strength steel parts used in aircraft. Although a large amount of hydrogen may be picked up in chemical pickling used to clean off scale, plating which frequently follows cleaning causes the major amount of trouble.

Three approaches to a solution of this problem are:

1. Electroplate only a flash coat of cadmium on the metal, which, because of its thinness, could be baked out in a short time. Upon dropping back to room temperature, this thin coat of cadmium acts as an effective barrier to further penetration of hydrogen.

2. Control plating conditions so that the cadmium plate is porous. During the baking operation, the hydrogen can then escape from the base metal through the pores, and the baking time is considerably reduced.

3. Vacuum deposit a plate which may or may not be subsequently electroplated.

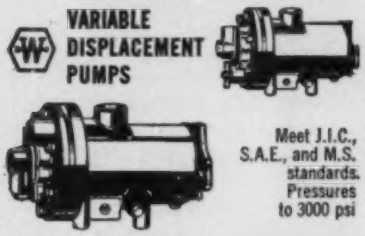
Flakes and Weld Cracking: Other large areas in which the effects of true hydrogen embrittlement are highly damaging are in the production of large forgings and in welding, particularly electric-arc welding. The type of damage encountered in forgings is called hairline cracking or flaking. A section through the forging reveals a multitude of fine cracks. Although the damage from these defects is permanent, it is still a form of true hydrogen embrittlement which occurs during processing rather than use.

The normal procedure for preventing flaking is soaking the billet at high temperature to allow the hydrogen to diffuse out before transforming the steel. But this procedure takes too long, hence the necessity for vacuum pouring.

Hydrogen damage in welding is reduced by using dry electrodes which produce the lowest hydrogen and still fulfill the requirements for the weld. Reducing the rate of cooling in critical temperature ranges below 300 C is also effective. Post-

WEATHERHEAD
HYDRAULIC POWER
Components

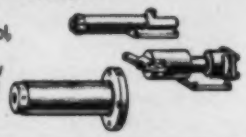
VARIABLE DISPLACEMENT PUMPS



Meet J.I.C., S.A.E., and M.S. standards. Pressures to 3000 psi

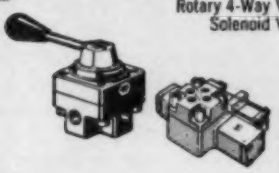
PUMP CONTROLS

Pressure Control, Automatic (Constant) Flow Control, Manual Displacement Control



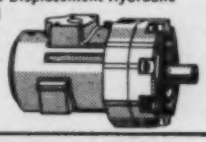
DIRECTIONAL CONTROLS

Rotary 4-Way Valves
Solenoid Valves



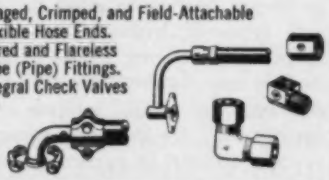
HYDRAULIC DRIVES

Fixed Displacement Hydraulic Motors, Reversible Variable Displacement Hydraulic Motors (Integrated Torque and Speed Control)



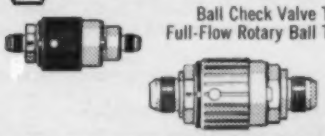
HIGH PRESSURE HOSE AND FITTINGS

Swaged, Crimped, and Field-Attachable Flexible Hose Ends. Flared and Flareless Tube (Pipe) Fittings. Integral Check Valves



SELF-SEALING COUPLINGS

Ball Check Valve Type
Full-Flow Rotary Ball Type



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Send for Bridgeport's Forgings Book which describes how these major benefits can lower costs for you.

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Circle 301 on Page 19

In coils. Thicknesses from .020 to .070 in., widths of 2, 4, 6, 8 in. Ideal for punched parts under static or dynamic loads (gaskets, washers, closure liners, etc.).

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Circle 302 on Page 19

Here's How Haveg Solved the Problem... with HAVELEX®

PRECISION MOLDED RIGID INORGANIC INSULATING MATERIAL

PROBLEM: To produce specialized lighting for vehicular tunnels, underpasses, walkways, marquees, and other places where severe ambient conditions exist (i.e., temperature, fog, spray, exhaust fumes, etc.) but where ease of servicing is vital.

SOLUTION: Haveg engineers working closely with The Simes Company, College Point, Long Island, New York, created a double contact insulation unit which permits energizing of fluorescent tubes sealed in glass jackets *from one end only*.

Double electrical contact was achieved by molding an outer brass tube (1¼" diameter) and a center brass contact pin (¼" diameter) integrally insulated with enduring Havelex. Chrome and silver plating was applied (after molding) to selected areas of the exposed brass to further enhance operating characteristics.

Haveg engineers welcome the opportunity to work with you on your particular project—to help you "Keep ahead with Haveg." Remember—Havelex offers all of these unique features: **Dimensional Stability • 1000°F. Continuous Temperature Resistance • Dielectric Strength • Mechanical Strength • Low Loss, Low Power Factor • Arc Resistance • No Moisture Absorption • Integrally Molded Metal Inserts • Hermetically Sealed Inserts.**

Please address inquiries to Sales Manager, Havelex

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weld heat treatment immediately after welding is beneficial, but not as effective as preheating.

Permanent Damage: In addition to the clear-cut permanent damage resulting from hydrogen attack or from true hydrogen embrittlement, there is another form of permanent damage. This is apparently produced by hydrogen alone, without the necessity of stresses or a second phase, although these do promote it. This type of damage appears primarily in the form of surface blisters and cracks.

Since this damage is permanent, it must be prevented or at least inhibited in commercial structures where corrosion is the primary cause. This is accomplished by using corrosion-resistant steels and by using chemicals to inhibit corrosion. The latter are the more economical, whenever effective. In electrochemical processes, reducing the current density reduces the blistering.

Theories of true hydrogen embrittlement and variations on them are almost as numerous as the investigators who have studied this type of failure. Since none is consistent with all the accumulated experimental evidence gathered both in the laboratory and from industrial experience, none is operationally very useful to the engineer. He should rather apply the general rules derived from this mass of empirical knowledge to the solution of his problems, bearing in mind the several types of hydrogen embrittlement with differing modes of solution. It may also be necessary to implement the available data with further tests designed to evaluate a specific material or particular condition.

"Hydrogen Embrittlement in Engineering Materials," General Electric Research Laboratory Bulletin, *Fall*, 1961, *pp.* 14 *to* 18.

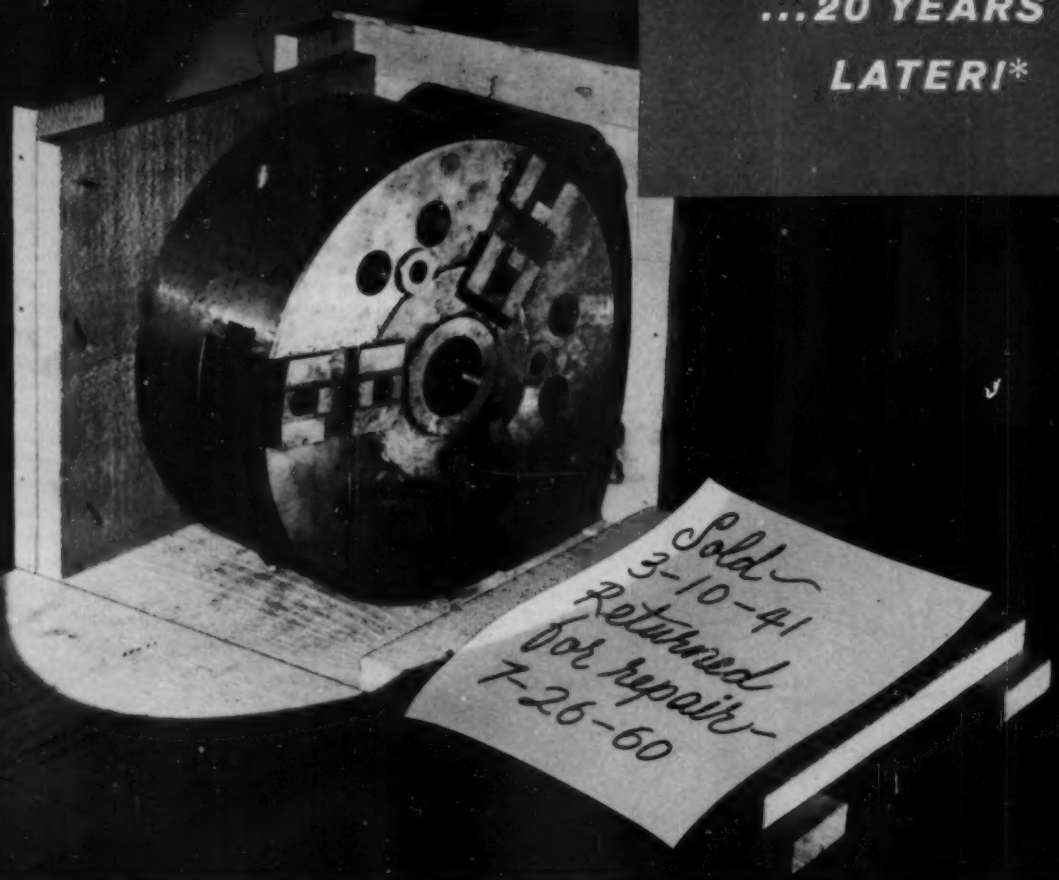
bearings

Oil-Viscosity Effects On Bearing-Ball Fatigue

Fred G. Rounds, General Motors Corp., Warren, Mich.

Results of four-ball fatigue tests run

the chuck that came back ...20 YEARS LATER!*



This chuck was returned for refurbishing after 20 years of service!

Actually, this is not an out-of-the-ordinary service record for Logan chucks, because they are built throughout with extra factors of strength and durability to resist deflection, misalignment and wear—and to deliver accurate, dependable and efficient service year after year on any type of operation.

If you would like more information about these rugged, long-lasting air and hydraulic chucks, or any of Logan's other products, just fill out the coupon below.

**Customer's name furnished upon request.*

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AIR AND HYDRAULIC OPERATED MACHINES

Check the items you want, fill in your name and address, tear out and mail to:

Logansport Machine Co., Inc. • 710 Center Avenue, Logansport, Indiana

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___300-1 CHUCKS
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Circle 304 on Page 19

Are Small Precision Metal Parts Getting In Your Hair?

If you need precision in small metal parts you can get it from Torrington—plus exactly the right finish, temper and hardness required for your needs. Moreover, Torrington can produce such parts at high speed and a remarkably economical cost. We are the leading specialist in this field—with the specialized skills, engineering experience and facilities to save you money. If you have small parts to be manufactured in large quantities why not let Torrington solve your entire problem. Let us hear from you and your request will receive prompt action.

progress through precision **SPECIAL METAL PARTS**

THE TORRINGTON COMPANY Torrington, Conn.

on sixty base oils selected from eleven different chemical classes.

Thirty - to - one differences in fatigue life are observed with different lubricants.

Among the lubricant classes giving the longest lives were the diesters and the polyphenyl ethers, whereas the fatty acids and halogenated hydrocarbons were the least desirable. Lubricant properties that seem to be controlling fatigue are viscosity, molecular shape, reactivity or polarity, and antiwear characteristics.

For the mineral oils and some synthetics, fatigue life doubled for a tenfold increase in viscosity at 210 F whereas, for other synthetic fluids, life was independent or decreased with increasing viscosity.

Although an optimum wear rate for maximum life was observed, for the base oils increasing wear reduced life. These observations indicate that physical and chemical processes occurring at the contacting surfaces have a pronounced effect on fatigue of bearings.

ASLE Preprint No. 61 LC-13, "Effect of Base Oil Viscosity and Type on Bearing Ball Fatigue," presented at the ASLE/ ASME Lubrication Conference, Chicago, October, 1961, 11 pp.

materials

Cermets' Characteristics at High Temperature, High Vacuum

R. D. Brown, senior research engineer, Dept. of Aerospace Propulsion Research; R. A. Burton, acting manager, Lubrication Section; and P. M. Ku, manager, Research Section, Dept. of Engines, Fuels, and Lubricants, Southwest Research Institute, San Antonio, Texas

Friction and wear characteristics of several bearing substrate materials and lubricants, over a temperature range from ambient to 2000 F, and in normal atmosphere with pressure varied from 760 to 10^{-6} mm Hg.

The sliding speed was 14 to 20 fpm. The load ranged from 1500 to 15,000 psi.

Two oxide-bonded cermets (Cr-Al_2O_3-W and Cr-Al_2O_3-Mo-TiO_2 were found to exhibit low wear and moderate friction when run against themselves throughout a wide range of test conditions. A third cermet (Cr-Al_2O_3) showed very poor frictional properties. Three high tem-

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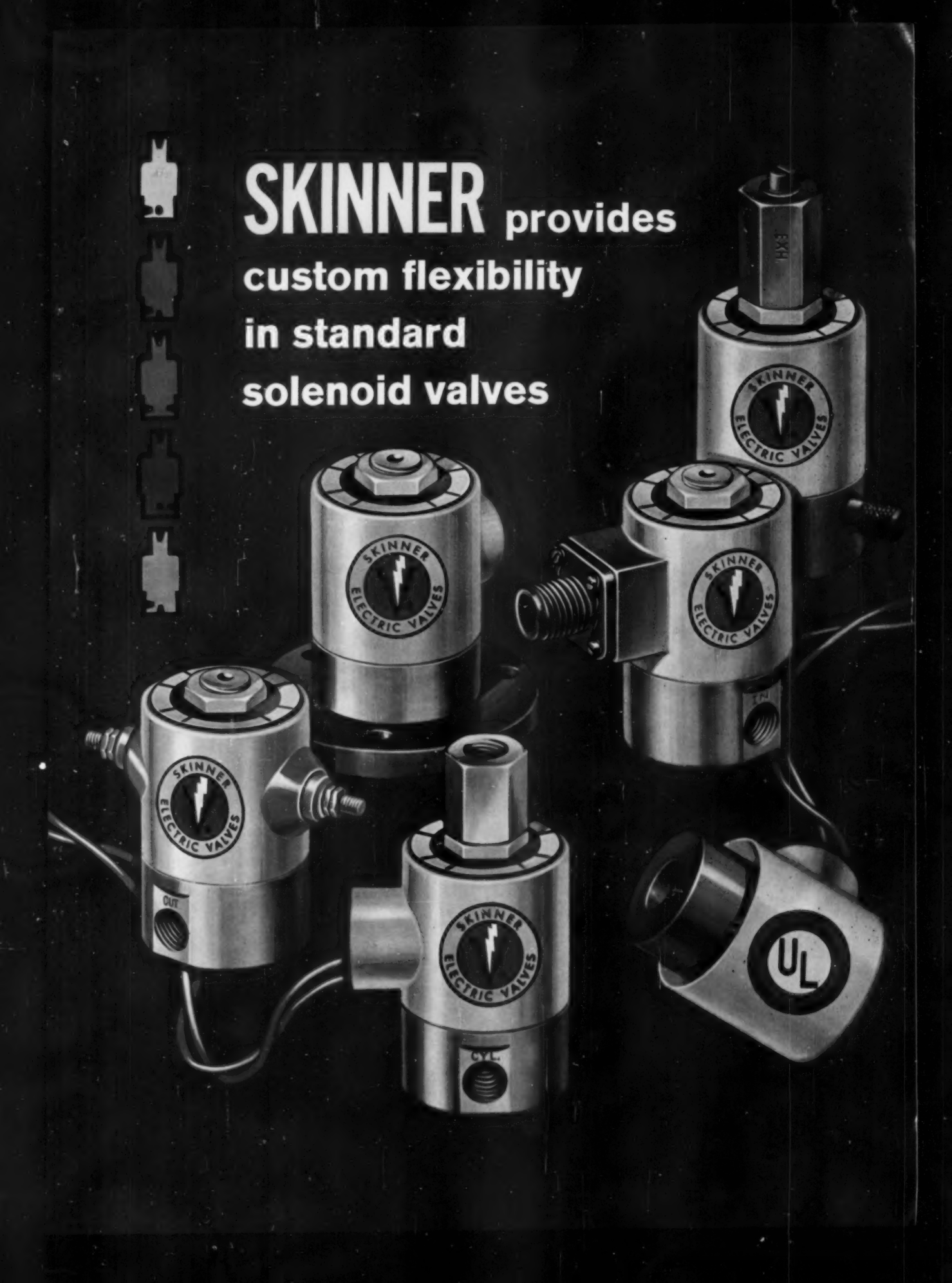
Circle 306 on Page 19→


SKINNER provides
custom flexibility
in standard
solenoid valves
SKINNER
ELECTRIC VALVES
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UL

Versatile, top quality V5, X5 line offers wide range of options

Skinner's two-way and three-way V5, X5 series of solenoid valves has earned the description—"The Universal Line." With more than 100,000 variations possible, V5, X5 valves are available for every conceivable application. And top quality is emphasized with bubbletight sealing, and stainless steel body, plunger and sleeve assembly. Precision machining, unique welding techniques, specially designed and developed machinery and manufacturing methods are all used by Skinner to produce the best valves made. These valves are small, yet handle operating pressures as high as 3000 psi. They accommodate all media that do not corrode stainless steel. And no other solenoid valves offer so many optional features. Check the following options.

FLOW CONTROL

Precise, accurate control of media flow is possible with all Skinner V5, X5 valves. Both two-way and three-way valves are available with adjustable flow in the main stream, and with manual override. Two-way valves are also available with adjustable bypass. Exhaust flow can be controlled in three-way valves.

ELECTRICAL HOUSINGS

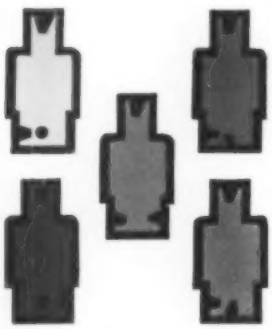
Skinner offers an electrical housing for any application. Some of the most common are:

- standard ½" NPT conduit
- grommet outlet
- single or double automotive terminals
- JIC housings with integral junction box
- AN connector for military applications
- strain relief connector for quick disconnect

All housings are steel, plated for wear and appearance, and can be rotated 360° for easy installation.

PORTING

Restrictions of installation or application, and mounting are minimized because Skinner provides a wide variety of port location options. V5, X5 valves are available with ports at right or left angles, on bottom, top, and sides for virtually all combinations of flow.



MOUNTING

Skinner V5, X5 valves are provided with tapped holes for normal mounting, with mounting brackets for panel or other surface, or with flange for direct mounting without threaded pipe connections.

The Skinner V5, X5 series of two-way and three-way solenoid valves provides top quality design with orifices from 1/32" to 3/8" diameter, normally open, normally closed, dual purpose, directional control and multi-purpose, in standard and explosion-proof construction. Also included in this line is a three-way quick-exhaust type which is designed with an additional port to exhaust cylinders 4 times faster than standard types.

COILS

Skinner V5, X5 valves are available with coils of many types for most DC and AC voltages at 25, 50 and 60 cycle frequencies. Whether your requirements are for continuous or intermittent performance, in tropical, high moisture or high temperature environments, or for dual voltage, Skinner UL approved coils are available with leads of several types and lengths.

• • •

Typical applications—machine tools, cylinder control, instrumentation and automation of all kinds, laundry equipment, aircraft and missiles, etc. For catalogs and complete information contact a Skinner Distributor listed in the Yellow Pages or write us at the address below.

When you specify solenoid valves, specify Skinner. Skinner solenoid valves are distributed internationally.

SKINNER ELECTRIC VALVES

THE CREST OF QUALITY

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THE SKINNER CHUCK COMPANY • NEW BRITAIN, CONNECTICUT, U.S.A.

PRINTED IN U.S.A.

perature alloys were also investigated for purposes of comparison.

Test results are also presented which indicate that two of the cermets were effectively lubricated by precious metal films.

ASLE Preprint No. 61 LC-3, "Friction and Wear Characteristics of Cermets at High Temperature and High Vacuum," presented at the ASLE/ASME Lubrication Conference, Chicago, October, 1961, 8 pp.

lubrication

Steel Surface Changes During Extreme-Pressure Lubrication

Douglas Godfrey, California Research Corp., Richmond, Calif.

Effects of SAE extreme-pressure runs on unfailed hypoid gear teeth in sulfurized mineral oil.

1. Sulfurized mineral oil promotes oxidation of steel under extreme-pressure conditions. Iron sulfides are a minor constituent, but necessary for high load-carrying capacity.
2. Silicon is present in this type of extreme-pressure film. Theoretically, its presence as SiO_2 or silicides should be beneficial due to improved inertness, adhesion and cohesion of films, and hardness of surface material.
3. Organic silicon compounds as additives for petroleum oils decrease friction and wear and provide a moderate increase in load-carrying capacity in bench tests. Poly (methylphenylsiloxane) produces a synergistic effect when used with sulfur, chlorine, and phosphorus in a gear oil, in the SAE machine.
4. The presence of iron oxides, a carbide and silicon, in addition to iron sulfide, in the surface of steel which was lubricated with sulfurized oil indicates that several chemical mechanisms are occurring during extreme-pressure lubrication.

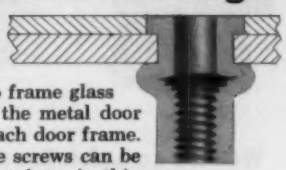
ASLE Preprint No. 61 LC-5, "Chemical Changes in Steel Surfaces During Extreme Pressure Lubrication," presented at the ASLE/ASME Lubrication Conference, Chicago, October, 1961, 8 pp.

Effect of Oil Viscosity on Metal Contact and Friction

M. J. Furey and J. K. Appeldoorn, Products Research Div., Esso Research and Engineering Co., Linden, N. J.

Effects of lubricant viscosity on metallic contact and friction in the

RIVNUTS® make sturdy nutplates for door hinges



Corridors of the new Atlanta Merchandise Mart are lined with attractive display rooms. The modular partitions, designed by Shower Door Company of America, use aluminum extrusions to frame glass and doorways. Sturdy nutplates are provided in the metal door jamb by installing twelve RIVNUTS® fasteners in each door frame. RIVNUTS® provide several threads so that hinge screws can be fastened securely. These fasteners are ideal for nutplates in thin material. RIVNUTS® are one-piece blind rivets with internal threads. To see if they can help on *your* fastening problems, please send a print of your part. For bulletin, see *Sweet's Product Design File*, or write *Dept. MD-12, B. F. Goodrich Aerospace and Defense Products, a division of The B. F. Goodrich Company, Akron, Ohio. In Canada: Kitchener, Ontario.*

B.F.Goodrich Rivnuts

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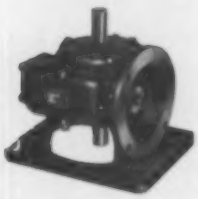
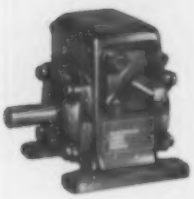
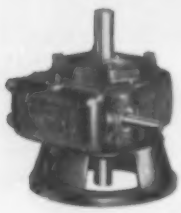
Circle 307 on Page 19

PERFECTION
Worm Gear
SPEED REDUCERS







One of our major capabilities is to design, develop and produce speed reducers that will insure maximum performance and economy in your operation. Our experience in the special problems and objectives of power transmission is broad and deep. The men at American Stock Gear having this important capability, use the most advanced analytical engineering facilities to design speed reducers to meet tomorrows needs.

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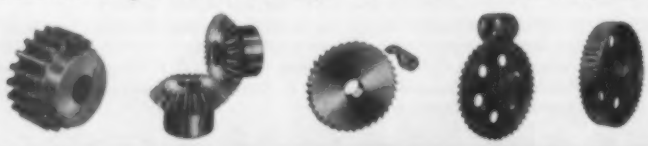
We make a complete line of stock gears. Send for Gear catalog No. 360.



AMERICAN STOCK GEAR DIVISION
PERFECTION GEAR COMPANY, HARVEY, ILLINOIS

transition zone between hydrodynamic and boundary lubrication. The system tested was one of pure sliding and relatively high contact stress, namely, a fixed steel ball on a rotating steel cylinder.

Increase in the viscosity of Newtonian fluids (mineral oils), over the range from 2 to 1100 centipoises, caused a decrease in metallic contact—the effect becoming progressively more pronounced at higher viscosities.

ASLE Preprint No. 61 LC-8, "The Effect of Lubricant Viscosity on Metallic Contact and Friction in a Sliding System," presented at the ASLE/ASME Lubrication Conference, Chicago, October, 1961, 9 pp.

Properties and Uses of Super-Refined Mineral Oils

E. E. Klaus, associate research professor of petroleum chemistry; E. J. Tewksbury, instructor in petroleum chemistry; and M. R. Fenske, head, Dept. of Chemical Engineering and director, Petroleum Refining Laboratory, Pennsylvania State University, University Park, Pa.

Super-refined mineral oils prepared from the conventional lubricant fractions of petroleum.

Resultant hydrocarbon fluids exhibit a liquid range of −75 F to above 700 F, good thermal stability to 700 F, excellent lubricity properties, and additive response (for foaming, oxidation, corrosion, wear, and lubrication) of the same order of magnitude as the high-quality organic esters. The super-refined mineral oils show unusual low temperature viscosity properties and blending characteristics.

ASLE Preprint No. 61 LC-10, "Preparation, Properties, and Some Applications of Super-Refined Mineral Oils," presented at the ASLE/ASME Lubrication Conference, Chicago, October, 1961, 11 pp.

TO OBTAIN COPIES of papers or articles abstracted here, write directly to:

ASLE—American Society of Lubrication Engineers, 5 North Wabash Ave., Chicago 2, Ill.; papers 50 cents to members, 75 cents to nonmembers.

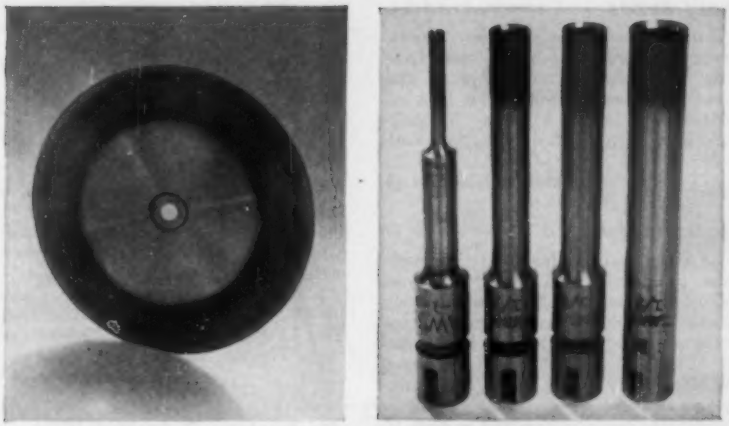
ASME—American Society of Mechanical Engineers, United Engineering Center, 345 East 47th St., New York 17, N. Y., papers 50 cents to members, one dollar to nonmembers.

GE Research Laboratory Bulletin, P. O. Box 1088, Schenectady, N. Y.

Linde Coatings & materials News

LINDE COMPANY, DIVISION OF UNION CARBIDE CORPORATION

Long wear for precision cutting parts now comes in thin coatings—.001" thick



Two important industrial cutting tools whose working lives have been multiplied by LINDE Flame-Plating tungsten carbide coatings: Rubber skiving knives (l.) and paper drills.

SUPER-THIN coatings of tungsten carbide and aluminum oxide—in the .00075" to .002" range of thickness—now keep many industrial cutting surfaces on the job many times longer than previously, yet preserve the precision fit needed for optimum cutting. The result: important savings in downtime and operating costs.

These tough, long-life precision coatings are applied by LINDE's Flame-Plating process, which "blasts" molten particles of tungsten carbide onto specified areas of wearing surfaces until the particles are built up to the desired degree of thickness.

Typical examples of longer wear

Because their cutting surfaces are Flame-Plated with tungsten carbide coating, rubber skiving knives that formerly required resharpening after every shift now stay in use 15 times longer. The knives also have the advantage of a self-sharpening effect. As the softer steel base wears more rapidly than the hard, tungsten carbide coating, a sharp edge is always presented to the material being cut.

Tungsten carbide coating enables serrated knives used in cutting plastic sheeting to process three times as much material before the first re-sharpening is necessary.

A coating of .001" thickness on the inside cutting surface of surgical shears has reduced their rate of wear by as much as 33 percent.

Flame-Plating proved so revolutionary for household cutlery that the manufacturer built his merchandising theme around *"The Greatest Development in 2000 Years of Cutlery Making—a Cutting Edge of Tungsten Carbide."*

Solves many wear problems

Tungsten carbide coatings of microinches thickness are equally effective wherever metal parts or working surfaces are exposed to abrasion, galling, erosion, fretting, corrosion, or high-temperature wear. Coatings are applied by the LINDE's 6,000-degree Flame-Plating process without distortion of the work piece or changes in properties of base metals.

For full information on Flame-Plating for your particular application, check and mail the coupon below.

Need to production-polish tungsten carbide surfaces?

It's easy with LINDE metallographic production-polishing aluminas—available in grades for three types of finishing: For high stock removal, 1 micron C; for moderate stock removal and ¼ rms finish, 0.3 micron A; for super polish, 0.05 micron B.

LINDE has developed special techniques for production-polishing of semiconductors and soft metals (such as brass), also new ideas for production-polishing hard metals, including micrometer anvils, hardened bearing races, routine metallographic samples. Get help with polishing techniques to meet your requirements. Send coupon below.

Jet planes landed by ruby-against-sapphire wear pads

In the automatic landing computer of a modern jet interceptor, a tiny ruby ball held to tolerances of 30 millionths oscillates against a synthetic sapphire plate flat to 1/10 light band, as a reference plate for a computer to translate radar approach signals into hydraulic actions.

Approximate size: Ruby ball, sapphire plates.

A similar wear surface bears on the cam head. Certain fly wheel governors also have sapphire wear surfaces.

This 70,000 to 300,000 psi LINDE material has a hardness second only to diamond, unlubricated static friction coefficient of .18, and dynamic of .08 against itself in moderate loads. It is economically suited for wear applications such as gage points, textile guides, optical inspection flats, and flow valves. Send coupon for information.

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Please send data on the items checked:

- ☐ LINDE Flame-Plating Process
- ☐ LINDE Alumina Abrasive Powders
- ☐ LINDE Synthetic Sapphire & Ruby

UNION CARBIDE

LINDE COMPANY

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MUELLER HAS THE METHODS . . . when you "Let Mueller Make It", you are utilizing one single source that is able to produce parts any one of these ways: as forgings, impact extrusions, sintered metal parts, screw machine products, formed tube or as castings.

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In addition, Mueller Brass Co. has complete and modern facilities for performing all types of finishing and sub-assembly operations. Another plus value is nation-wide sales engineering service.

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PORT HURON 20, MICHIGAN

Helpful Literature for Design Engineers

For copies of any literature listed, circle Item Number on Yellow Card—page 19

Epoxy Resins

Compares 17 Randac epoxy resins, giving components, primary uses, handling characteristics, and physical and electrical properties. Material is in comparison-chart form. 4 pages. Mitchell-Rand Mfg. Corp., 51 Murray St., New York 7, N. Y.

Circle 501 on Page 19

Control Valves

Compares various features of control-valve construction and operation. Covers shutoff, maintenance, differences in body construction, and price comparison between the two primary types of control-valve design. Booklet SBV-1, 8 pages. Conoflow Corp., 2100 Arch St., Philadelphia 3 Pa.

Circle 502 on Page 19

Monoplanar Switching

Two bulletins discuss general advantages of monoplanar switching over conventional methods, and describe Uniplane multicircuit monoplanar switch kits. Each kit provides 528 different switch arrangements. Bulletins 6130 and 6131, 8 pages. Ucinite Co., Div., United-Carr Fastener Corp., Newtonville 60, Mass.

Circle 503 on Page 19

Servo Recorder

Covers models HR-80 and HR-87 T-Y recorders, designed to replace conventional strip-chart and circular-chart recorders for applications where a chart length of 10 or 15 in. will provide adequate resolution. Specifications for both models are included, as well as data on chart papers. 4 pages. P. O. Box 22234, Houston 27, Tex.

Circle 504 on Page 19

Electromechanical Components

Gives specifications for precision gears, magnetic clutches and brakes, differentials, couplings, gear heads, limit stops, bearings, electronic hardware, and other items with applications in the electromechanical field. Catalog 100, 140 pages. Siamco Div., Tech-Ohm Electronics Inc., 36-11 33rd St., Long Island City 6, N. Y.

Circle 505 on Page 19

Pressure Hose

Describes interlocked pressure hose for loading, unloading, and conveying steam, oil, tar, and asphalt. In addition to features and applications, shows specifications and working-pressure correction factors, discusses fittings, and shows typical assemblies available. Bulletin 15-E, 6 pages. Atlantic Metal Hose Co. Inc., 308 Dyckman St., New York 34, N. Y.

Circle 506 on Page 19

Bimetal Thermometers

Covers industrial, laboratory, Navy, and pocket types of bimetal thermometers. Includes data on special applications, special windows, corrosive conditions, and special wells for high-pressure or heavy-duty installations in any type of service. Catalog 09-100, 16 pages. Weston Instruments Div., Daystrom Inc., 614 Frelinghuysen Ave., Newark 14, N. J.

Circle 507 on Page 19

Electrostatic Generators

Describes line of electrostatic generators used in nuclear physics, insulation testing, electron microscopy and optics, X-ray generation, and electrostatic precipitation. Specifications cover models from 50 to 600 kv output. Features, applications, and principles of operation are included. 8 pages. Sames-USA, 30 Broad St., New York 4, N. Y.

Circle 508 on Page 19

Sealing Washers and Fasteners

Two data sheets discuss Barclad sealing washers and Barpad fasteners. Various types of the units are pictured, and materials and specifications are given. 2 pages. L. J. Barwood Mfg. Co. Inc., Everett 49, Mass.

Circle 509 on Page 19

Infrared Transmitting Materials

Reviews 15 materials, providing transmission curves and detailed properties on each. Among the properties covered are long wavelength transmission limit in microns, index of refraction, cold-water solubility, soluble solutions, maximum size, and relative cost. 4 pages. Servo Corp. of America, 111 New South Rd., Hicksville, L. I., N. Y.

Circle 510 on Page 19

Fluid Coupling

Discusses and illustrates VariDraulic drive, a controllable hydrostatic fluid coupling. Points out general features of the unit, includes data on the various types, and shows application photographs. 18 pages. Hydraulics Inc., Parsons, Kans.

Circle 511 on Page 19

MUELLER CAN MAKE MOST ANYTHING IN BRASS OR ALUMINUM FORGINGS...

Battleships are not our business, but we can make any practical size and shape forging, including cored forgings and those with bosses or cavities on two planes. (The ship model is made up from a number of production forgings.)

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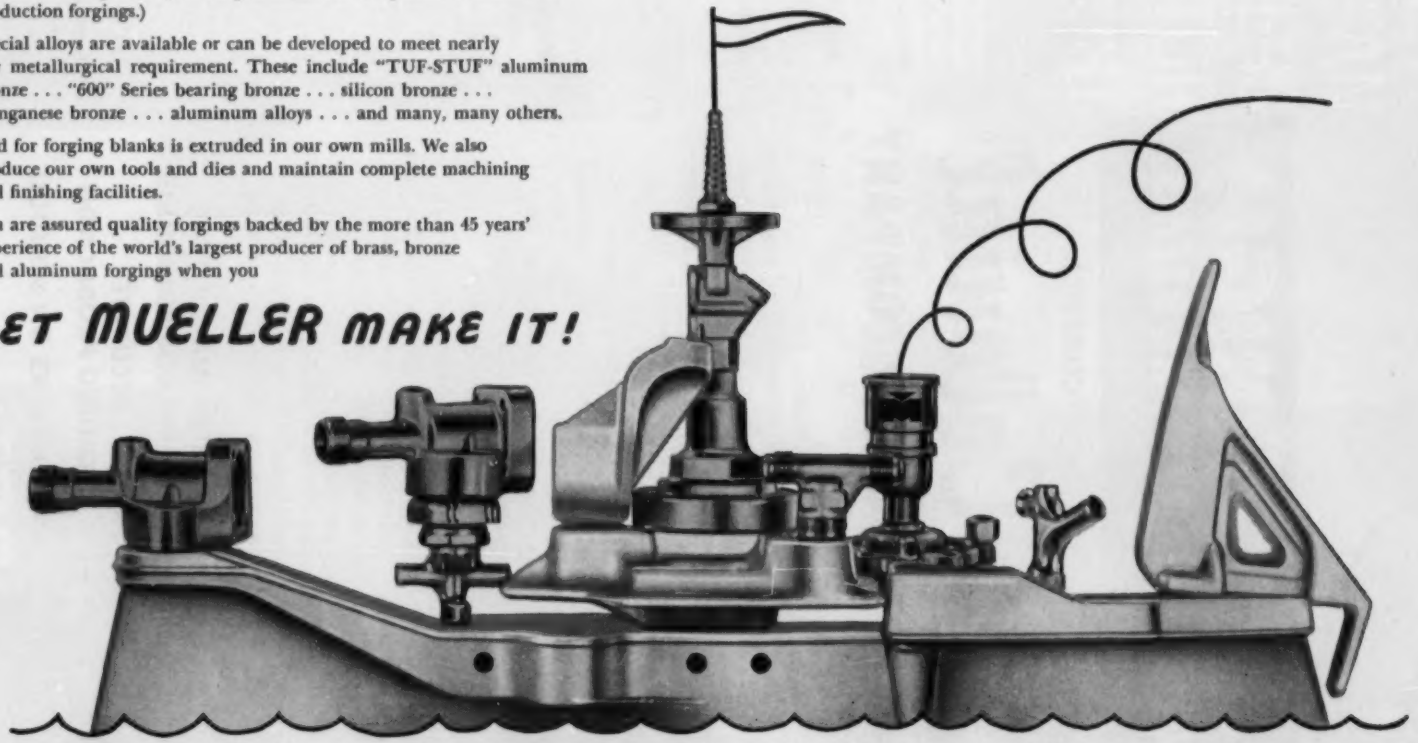

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Circle 310 on Page 19

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RUBBER PARTS PROBLEMS

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Circle 311 on Page 19

HELPFUL LITERATURE

Mechanical Counters

Describes and illustrates new line of 108 high-speed, low-torque, direct-drive mechanical counters for digital-readout applications. Gives full specifications for Veederline units available in single, dual, and tandem models. Selection material is included. Form 227864, 8 pages. Veeder Root Inc., 70 Sargeant St., Hartford 2, Conn.

Circle 512 on Page 19

Industrial Engine

Covers valve-in-head, air-cooled, V-460D 60-hp industrial-type engine. Brochure describes design and metallurgical improvements incorporated in the unit. Includes detailed specifications, installation drawings, and dimensions, and a list of optional equipment available for adapting the engine to specific heavy-duty applications. Bulletin S-282, 4 pages. Wisconsin Motor Corp., Dept. NR, Milwaukee 46, Wis.

Circle 513 on Page 19

Ball Radial Bearings

Gives specifications on Reali-Slim CP ball radial bearings, including information on 90 sizes of thin-section bearings in sizes from 4 to 12-in. bore with ¼ to 1-in. width and cross section. Other data include capacities, shaft and housing sizes, bearing internal clearances, shoulder diameters, material specifications, and mounting data. Bulletin S-141, 4 pages. Kaydon Engineering Corp., Muskegon, Mich.

Circle 514 on Page 19

Machined Bellows

Discusses machined bellows and their use in missile, nuclear, and chemical industries, in difficult temperature and pressure environments. Various types and their applications are shown. Bulletin 1401, 4 pages. Hydrodyne Corp., 7350 Coldwater Canyon Ave., North Hollywood, Calif.

Circle 515 on Page 19

Lock Nuts

Discusses Lokon prevailing-torque lock nuts of heat-treated alloy steel. Points out how the nuts operate, and gives specifications. Compression chart of lock nut reusability is included. Form L-101, 4 pages. Lokon Div., Allen Mfg. Co., Hartford 1, Conn.

Circle 516 on Page 19

Glass-Fiber-Reinforced Plastics

Lists glass-fiber fabrics and fibers, polyester and epoxy resins and catalysts, parting agents, and pigments. Available sizes and grades are shown under each material, along with short descriptions of properties and recommended applications. Property tables and application data on glass fiber cloths, polyester resins, and epoxy resins and hardeners are included. Catalog 2, 16 pages. Cadillac Plastic & Chemical Co., 15111 Second Ave., Detroit 3, Mich.

Circle 517 on Page 19

Circle 312 on Page 19→

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The use of a Torrington "R" Series fan often results in a lower horsepower requirement for a given air flow. Motor cost reductions of up to 20 dollars a unit can be realized. Advanced blade design with multiple pitch selection means high in application efficiency combined with low axial depth.

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Die stamped circuits are produced by a dry technique which employs a heated metal-cutting die to delineate the conductor pattern and bond it to the base material by activating the adhesive between the metal foil and the insulating material.

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Norristown, Pa.

Circle 313 on Page 19

HELPFUL LITERATURE

Bearing Data Sheet

Gives selection data on 143 standard and special design miniature and instrument bearings, ranging in size from 0.1562 to 1.04 in. OD. Data sheet covers 40 sizes, open and shielded, flanged and unflanged, including standard and narrow-width types as well as extra-large OD bearings for synchros. Engineering information includes static and dynamic ratings, running-torque values, radial-play ranges, lubricants, retainer types, nomenclature guide, and tolerances. Data Sheet M-3, 2 pages. Barden Corp., 200 Park Ave., Danbury, Conn.

Circle 518 on Page 19

Level Recorder

Two technical reviews cover "RMS Recording of Narrow Band Noise With A Level Recorder" and "Effective Averaging Time of an RMS Level Recorder." Influences in the level recorder that affect the measurement of the theoretically true RMS value of a statistically fluctuating signal are extensively explored. Bulletins TR-4-60 and TR-1-61, 22 pages each. B & K Instruments Inc., 3044 W. 106th St., Cleveland 11, Ohio.

Circle 519 on Page 19

Polarized Relays

Describes sensitive, small, high-speed relays which provide a wide selection of design parameters. Covers design features, coil details, contact materials, enclosures and bases, and circuit applications. Catalog F, 6 pages. Magnetic Devices Inc., 712 East St., Frederick, Md.

Circle 520 on Page 19

Data Processing

Enlarged booklet presents systems applications involving tape-operated business machines. Flexowriter, Teledata, Collectadata, Add-Punch, and Computyper units are shown in various applications. 32 pages. Friden Inc., 97 Humboldt St., Rochester 2, N. Y.

Circle 521 on Page 19

Protective Coatings

Chart provides thermal, physical, chemical, and electrical characteristics of Humi-Seal protective coatings for electronic applications. Ten types are broken down by the AIEE thermal classification as well as 47 other specific characteristics for each type. Reverse side of the chart is a selector table for choosing the HumiSeal type best suited for the application. Chart C-503, 6 pages. Columbia Technical Corp., Woodside 77, N. Y.

Circle 522 on Page 19

Electromagnetic Flowmeter

Describes Mag-Pipe unit which measures the velocity of fluids from distilled water to high-conductivity chemicals. Lists specifications and mounting dimensions. Bulletin 98418, 8 pages. Taylor Instrument Companies, Rochester 1, N. Y.

Circle 523 on Page 19

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SEALOL "605"

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- Only one moving part
- Unlimited shelf life
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Because every "605" is suitable for a thousand and one different applications, you can reduce seal inventories and spares up to 40%. The secret is in the fact that every "605" is fully pressure balanced and uses no dynamic elastomers. Result? Unlimited shelf life and, if certain basic requirements are met, any place a compact "605" will fit, it will work.

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Circle 314 on Page 19

Industrial Wire Cloth

Describes engineering considerations for proper application of industrial wire cloth. Contains a glossary of terms, description of weave types, mesh size versus open-area tables, weight listings, application principles, and guides to the selection of proper metals and protective coatings. Catalog R-100, 28 pages. National-Standard Co., Dept. RDT, Niles, Mich.

Circle 524 on Page 19

DC Amplifier

Provides specifications and applications data for a floating, differential, dc amplifier which can be used for general laboratory purposes or with multichannel datalogging systems. Contains circuit diagrams and information on amplifier housings. Data Sheet 2-96, 4 pages. Kin Tel Div., Cohu Electronics Inc., 5725 Kearny Villa Rd., San Diego 12, Calif.

Circle 525 on Page 19

Stressed Panel Fasteners

Covers Zip-Loc fasteners in miniature and standard sizes. Includes specifications on each type, gives diagrams to show the stud-nut installation, and shows typical applications. Bulletin DF 166, 8 pages. Deutsch Fastener Corp., 14504 S. Figueroa St., Los Angeles, Calif.

Circle 526 on Page 19

Miniature Connectors

Contains data on Hyfen Bantam miniature round connectors that conform to MIL-C-26482. Includes specifications, dimensional drawings, tables, shell styles, and termination devices for shell sizes from No. 10 though No. 24. Additional technical and illustrative material explains polarization and points out specific design features. Catalog BHB, 32 pages. Burndy Corp., Norwalk, Conn.

Circle 527 on Page 19

Metallic Gaskets

Covers Spirotallic, metal-jacketed, flat-metal, corrugated, round cross-section, and heavy cross-section gaskets. Tells where the units are recommended, how they work, why they are suggested, and what constructions are available. Comprehensive selection charts are included. Booklet PK 152A, 28 pages. Packing & Friction Materials Div., Johns-Manville Co., 22 E. 40th St., New York 16, N. Y.

Circle 528 on Page 19

Hand Pumps

Describes 12 fluid-power hand pumps. Features of the pumps are enumerated, typical applications are given, and construction is shown with a detailed parts listing. Drawings and specifications for mounting pads are included. Service, operating, and maintenance instructions are given in abbreviated form. Catalog 100-C3, 8 pages. Commercial Shearing and Stamping Co., 1775 Logan Ave., Youngstown, Ohio.

Circle 529 on Page 19

Eliminate special sizes...fit more accurately!

S. S. White General Purpose "GP" Plastic Protectors are an improved way to protect your products during manufacturing, shipping and storage.

Each GP protector can be used as either a cap or a plug on all machine screw threads, pipe threads, and tubing in a range from ¼" to 2¼"... with an accurate, *engineered* fit. GP protectors eliminate special sizes and fit better!

"GP" protectors are made of a special grade of elastic polyethylene that cushions shock and is unaffected by oils, greases, acids and other common solvents. They have a "stay-put" fit, yet they are easy to grip for a quick, *non-shredding* removal.

Start now to *put an end* to customer complaints about damaged equipment. Use low cost GP protectors!

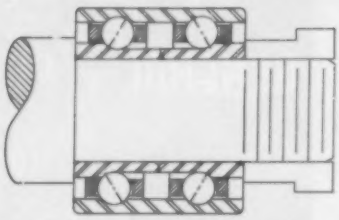
WRITE FOR BULLETIN 6104-GP
Complete details

S. S. White PLASTICS DIVISION
Dept. 4P, 10 East 40th Street, New York 16, N. Y.

Circle 315 on Page 19

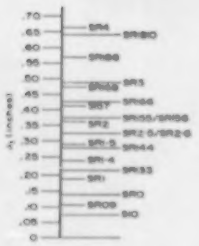
No. 4

ideas you can use in working with bearings

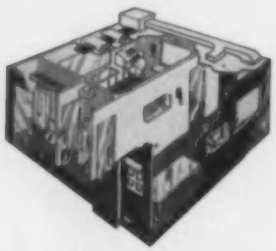


So-called "super duplex" bearings have two separable inner rings and a one-piece outer ring with two raceways which eliminates the possibility of angular or radial misalignment. Cherry-reamed ball pockets hold the balls firmly in the retainers when the inner rings are removed and make it possible to handle the outer ring, balls and retainer as a separate unit during installation in instruments.

For servomotor applications, it is necessary to use bearings of a low specified radial play in order to keep rotor shaft runout at a minimum. A radial play of .0002" — .0004" is commonly specified for such bearings. A side benefit is that low radial play will cause a maximum number of balls to share the load which is nearly always radial.



The linear speed with which bearing balls roll along the raceways is an important factor affecting bearing life, running noise, vibration and lubrication requirements. If, in selecting a bearing, the fundamental specifications have been satisfied and there is still a choice of size, a logical selection would be the one with the lowest ball rolling speed. In the chart above, ball rolling distance (S_1) x .00139 x bearing rpm = ball rolling speed in ft./sec.

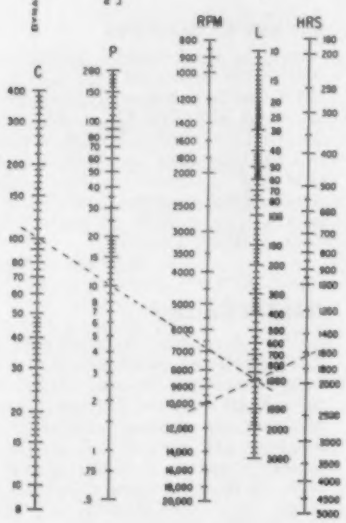


To a precision miniature bearing, a speck of dirt seems like a rock. To prevent such contamination from doing serious damage in the raceways, some form of environmental control is essential when handling or installing miniature or instrument ball bearings. One form is a "clean room", essentially a dust-controlled room-within-a-room. Another is individual dust-controlled hoods. Work tables should have a smooth, non-contaminating surface such as Formica or stainless steel.

150-page Design and Purchasing Manual is the most comprehensive treatise on miniature and instrument ball bearings ever published. Qualified design and specifications engineers, and procurement specialists, are welcome to a copy.

Load ratings of NHBB bearings provide a quick method of estimating bearing life.* Using nomograph at right, a load or "C" rating of 100 lbs. for a bearing loaded radially with 10 lbs.(P) could be expected to have a life(L) of 1,000 million revolutions assuming temperature is not a factor and the lubricant employed is adequate. At 10,000 RPM, the life would be 1670 hours. The C values for the various types of New Hampshire bearings made of stainless steel (AISI 440C) are included in the bearing tables. The C value for chrome steel bearings is approximately 1.2 times the listed value, and the C value for beryllium copper bearings is approximately one third the listed value.

LOAD NOMOGRAPH



*Rating life of a group of apparently identical ball bearings is defined as the number of revolutions that 90% of the group will complete or exceed before the first evidence of fatigue develops (approx. 1/5 of average life).

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PETERBOROUGH, N. H.

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bearings
from
New
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Now you can protect the life and running quality of New Hampshire bearings on applications where lubricants tend to work out and atmospheric contaminants tend to work in.

The miniature and instrument bearings listed below are equipped with positive, contact-type seals which keep lubricant in and dirt out.

BORE +.0000 −.00015	OUTSIDE DIAMETER +.0000 −.00015	WIDTH +.000 −.001	BEARING NUMBER	C RATING
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.0781	.2500	.1406	SR1-4LL3	30
.0937	.3125	.1406	SR1-5LL3	50
.1250	.3125	.1406	SR2-5LL3	51
.1250	.3750	.1562	SR2LL3	58
.1875	.3750	.1250	SR166LL3	64
.1875	.5000	.1960	SR3LL3	106
.2500	.5000	.1875	SR188LL3	97
.2500	.6250	.1960	SR4LL3	134
.3125	.5000	.1562	SR1810LL3	47

Write for complete information

NEW HAMPSHIRE BALL BEARINGS, INC.
PETERBOROUGH, N. H.

Self-Sticking Tapes

Describes new self-sticking tapes in transparent colors with glossy or matte surface. In addition to suggested usage and descriptive information on both types of tapes, brochure carries a list of colors, sizes, prices, and information on ordering. Actual samples of the glossy and matte-surface tapes are included. 4 pages. ACS Tapes Inc., 217 California St., Newton 58, Mass.

Circle 530 on Page 19

Silicon Rectifiers

Covers standard silicon power rectifiers and rectifier stacks used in battery chargers, instrumentation and electronic circuitry, railway signaling, electroplating, and similar services. Consists of 12 individual data bulletins describing eight basic silicon power rectifiers and their corresponding standard rectifier stack assemblies. Contains tabulations of electrical data, characteristics curves, and dimensional diagrams. 44 pages. Rectifier-Capacitor Div., Fansteel Metallurgical Corp., North Chicago, Ill.

Circle 531 on Page 19

Plastic-Clad Pipe

Polyether plastic-clad pipe for high-order corrosion protection is described. Illustrates properties and applications of the Penton-clad pipe and fittings which resist the corrosive attack of a wide variety of chemicals and provide inside-outside protection at temperatures to 275 F. Chemical resistance charts are included, along with methods of evaluating service performance in specific chemical environments. Also contained are range of pipe sizes available and installation advantages and instructions. Bulletin BR 13, 8 pages. Polymer Corp., 2120 Fairmont Ave., Reading, Pa.

Circle 532 on Page 19

Laminated Phenolic Plastic

Describes Ohmoid laminated, thermosetting phenolic plastic composed of paper, canvas, or linen base impregnated with phenolic resin and bonded under heat and pressure. Gives general properties, shows components made of the laminate, and gives sheet weights and tolerances, rod and tube sizes. 4 pages. Wilmington Fibre Specialty Co., New Castle, Del.

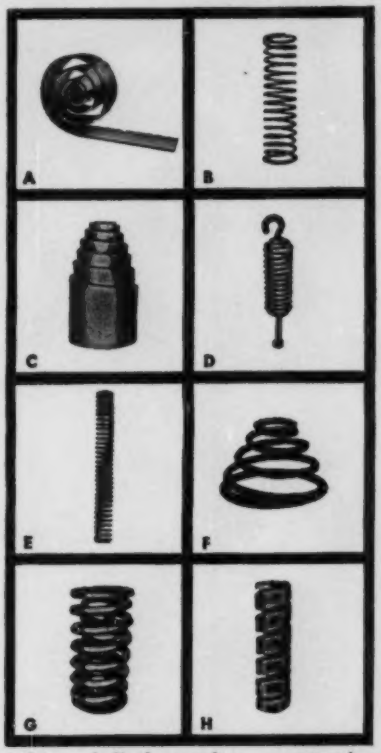
Circle 533 on Page 19

High-Pressure Flowmeter

Describes new 2-in., high-pressure flowmeter designed for both liquid and gas applications. Design and construction information, connections and dimensions, and pressure-drop charts are included. Vortex-velocity principle of operation is described, along with specific advantages and recommended applications for the liquid and the gas models. Catalog Sheet CM-49, 2 pages. Rotron Controls, Div., Rotron Mfg. Co. Inc., Woodstock, N. Y.

Circle 534 on Page 19

Can you identify these springs?



A. flat B. helical C. volute D. extension E. helical F. cone G. helical, triple-coil H. rectangular section

Over One Million ALCO SPRING DESIGNS

ALCO's complete line of "performance-rated" springs ranges from small springs for light work to heavy-duty triple-coil springs for heavy, sustained work.

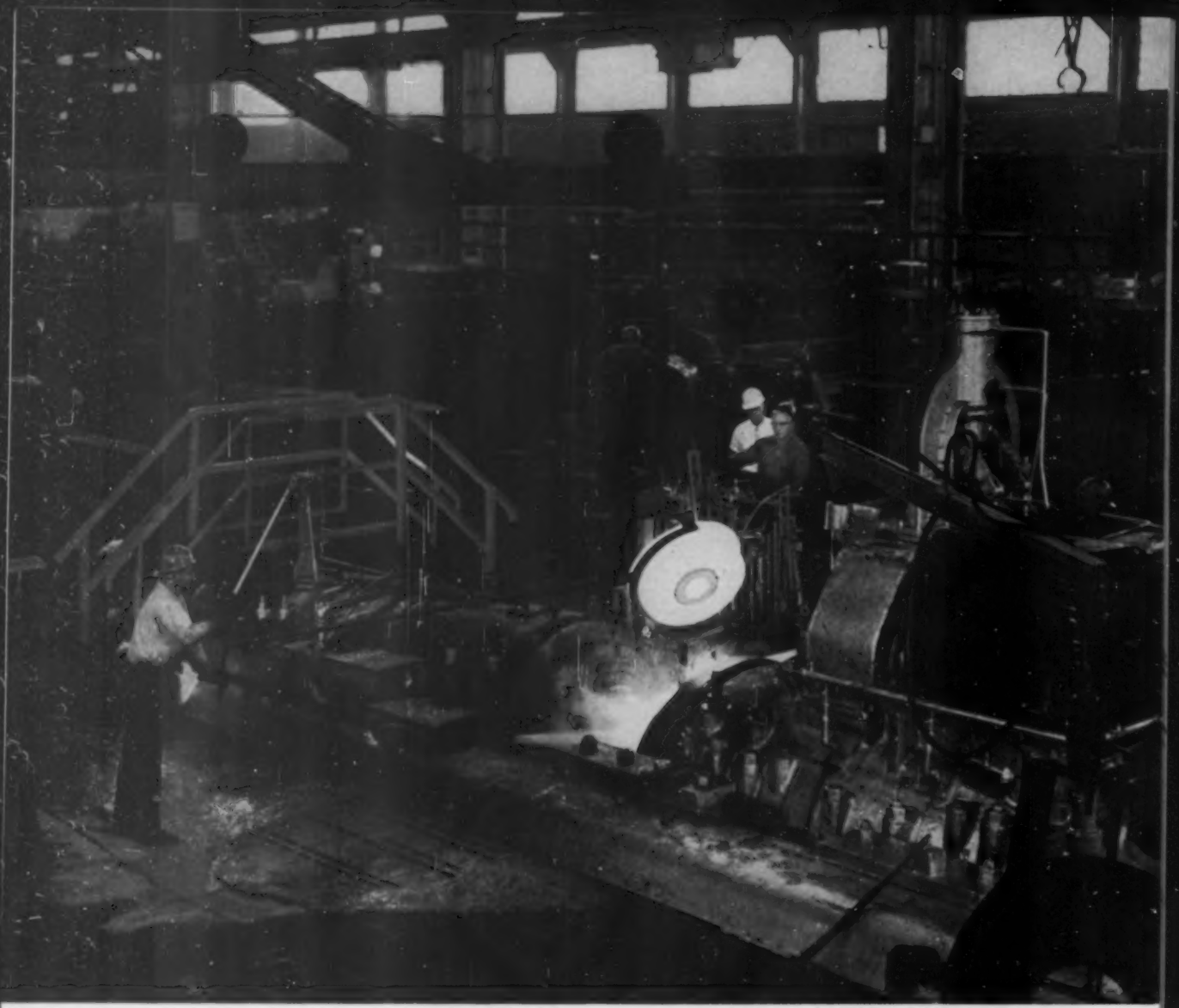
In over 80 years, ALCO engineers have produced more than one million spring designs to serve almost every conceivable application.

For your next spring job, contact your nearest ALCO sales office. To obtain brochure, ALCO *Springs for Industry*, write to ALCO Products, Inc., Dept. 160, Schenectady, N. Y.

ALCO

ALCO PRODUCTS, INC.
NEW YORK
SALES OFFICES IN PRINCIPAL CITIES

Circle 317 on Page 19



Bethlehem's unique Slick Mill, named after its inventor, forges and rolls a circular forging—100 to 2,000 lb—in one minute.

SLICK

This is our Slick mill. It's the only one of its kind. It turns out a circular forging—gear blank, sheave wheel, compressor wheel, tire mold, or crane wheel—*in less than one minute.*

Thanks to quick die changes, it handles production runs as small as 25 to 50 pieces almost as economically as runs ten times as large.

It cuts conventional die charges in half because contact between die and work is so brief.

It produces light-weight sections without sacrificing strength . . . forgings with excellent grain flow, machinability, and soundness.

It's a pretty slick mill.

But that's not why it's *called* a Slick Mill. Edwin E. Slick is the name of the man who invented this unique mill. If you'd like to know more about how it can help you cut the cost of circular products, ask our nearest sales office. Or write to us at Bethlehem, Pa.

Steel *for Strength*
. . . Economy
. . . Versatility

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
Export Sales: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

Circle 318 on Page 19

Motors, Generators, Synchros

"Technical Information For The Engineer —Servo Motors, Motor Generators, Synchros" details the theory, performance, application, construction, and testing of rotary-wound components such as motors, tachometers, generators, mechanical filters, synchros, and resolvers. Tabulations give operating characteristics for more than 250 different rotary-wound components used in servo systems, computers, and other applications. Gearhead data are also included. 60 pages. Kearfott Div., General Precision Inc., 1150 McBride Ave.,

Circle 535 on Page 19

Rod and Sheet

Multicolored chart with photographs of end-products tabulates a complete picture of rod and sheet stock available, from copolystyrene rod to foam materials. A large variety of material is shown. Physical and electrical properties are tabulated with curves plotted as a function of varying dielectric constant. 6 pages. Emerson & Cuming Inc., Canton, Mass.

Circle 536 on Page 19

Slip-Ring Assemblies

Covers scope and application of slip-ring assemblies, and gives specifications for various types. Places emphasis on the importance and interrelationship of slip-ring components, and on the use of these assemblies in the electric and electronic fields. Catalog SR-1, 16 pages. Superior Carbon Products Inc., 9115 George Ave., Cleveland 5, Ohio.

Circle 537 on Page 19

Water Pump

Describes Model W vane-type water pumps for use in drink-vending machines, carbonators, and similar applications. Contains technical information, including performance characteristics, flow characteristics, dimensional, and performance data. Catalog Section 112, 4 pages. Tuthill Pump Co., 939 E. 95th St., Chicago 19, Ill.

Circle 538 on Page 19

Preprinted Drafting Symbols

Discusses preprinted repetitive symbols and drawing details. Shows how to use the symbols, printed on triacetate sheets coated with water-clear adhesive. 6 pages. Stanpat Co., Whitestone 57, N. Y.

Circle 539 on Page 19

Glass-Fiber Insulation

Illustrates use of fibrous-glass insulating materials for industrial, military, and consumer applications. Specifications include composition, density, temperature ranges, and noise-reduction coefficients. Also covered is the molding of fibrous glass into almost any shape desired. Bulletin F101, 4 pages. Fibrous Glass Products Co., subsidiary of Pall Corp., Mountaintop, Pa.

Circle 540 on Page 19

ESSENTIAL TO NUMERICAL CONTROL

Maxitorq

ELECTRIC

CLUTCHES and BRAKES

COMPACT DESIGN • FAST RESPONSE
POSITIVE REMOTE CONTROL PERFORMANCE

Incorporating advanced design principles proved through years of service, the MAXITORQ Electric Clutch is well adapted to all types of machine drives. Simple in design . . . built to machine tool standards . . . requires no adjustments, can be used either as a clutch or brake. Disc separators not only separate discs, but also break up residual magnetism and result in extremely fast, positive action with no drag or heating in neutral. There are few moving parts. Electrical operating unit remains stationary — hence, no troublesome slip rings, brushes, or difficult wiring problems. Operation is on standard 100 V d.c. Other voltages on special order.

If you have a clutch or brake application where you are looking for NEW and IMPROVED performance, we invite you to bring the problem to us. Phone, wire or write Dept. MD for Bulletin No. 90.

FAST ACTING
POSITIVE ENGAGEMENT and RELEASE
REMOTE CONTROL
COMPACT DESIGN
SELF ADJUSTING
NO TROUBLESOME WIRING

THE CARLYLE JOHNSON MACHINE CO.
MANCHESTER, CONN.

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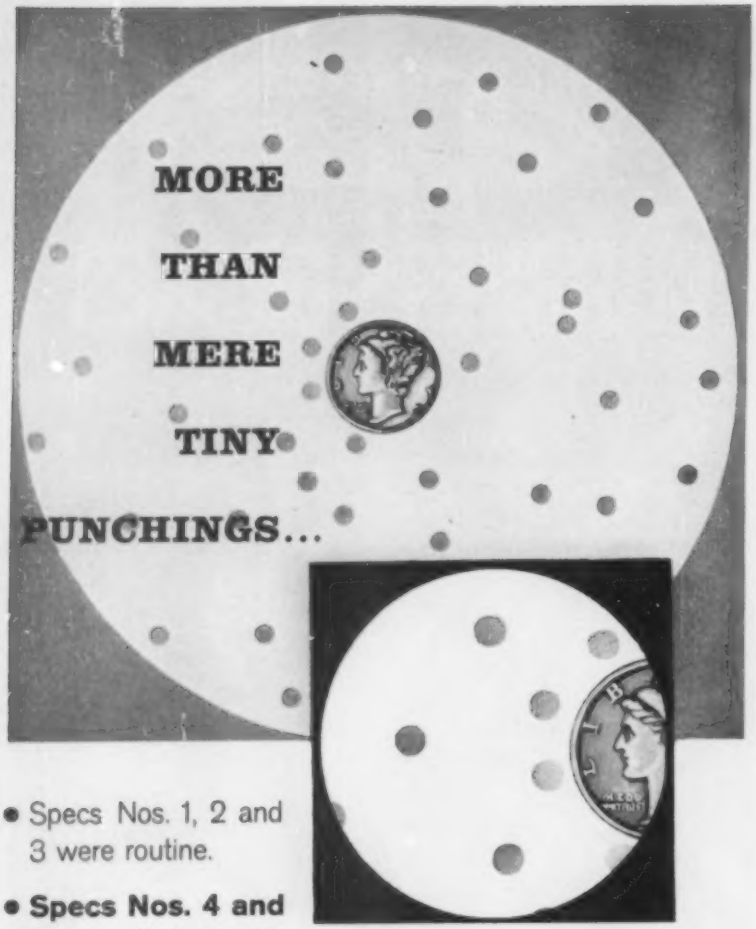


- Specs Nos. 1, 2 and 3 were routine.
- **Specs Nos. 4 and 5 were "unusual".**

What you are looking at are specimen holders for an electronic microscope. They're so small that it takes about 40 to cover a dime. Specifications as to kind of metal, diameter of wire and mesh might be considered routine. It's what we did with the cloth before punching and how we treated the punchings that are important. Spec No. 4 especially tested our manufacturing skills. No. 5 called for special cleaning.

We started with NEWARK Stainless Steel 200 x 200 Mesh Cloth woven with 0.0021 inch diameter wire. Cloth thickness was 0.0042 inches. Then we rolled or calendered the cloth very carefully to 0.0025 inch thickness. After clean-cut punching, we cleaned and passivated the pieces in dilute nitric acid, imparting to them an almost surgical cleanliness...a cleanliness which was retained through the packing. The discs had to be kept free of foreign matter.

As pointed out above, the cloth itself is not uncommon but the rolling and treatment were somewhat unusual. The skill in handling and quality of work typified by this job suggests the skill and quality of work available to you for any "wire cloth" insert project you have in mind. Incidentally, much of our work is in preparing "punchings" in all diameters in single pieces, in segments, or in sectors.

NEWARK for ACCURACY

Newark Wire Cloth COMPANY

351 Verona Avenue • Newark 4, New Jersey

Teletype: NK607 • Tel.: HUmboldt 3-7700

Circle 320 on Page 19

HELPFUL LITERATURE

Cold Extrusion

Discusses advantages of the cold-extrusion process. Photographs of typical cold-extruded parts are included. Type of steel required for cold extrusion, and the importance of selecting the right steel, are also covered. Booklet Adv. 1290, 8 pages. Republic Steel Corp., 1441 Republic Bldg., Cleveland 1, Ohio.

Circle 541 on Page 19

Copper-Zirconium Alloy

Contains a survey of the properties of Amzirc copper-zirconium alloy. Material combines retention of high strength at elevated temperatures with high conductivity. Describes the nature of the alloy, fabrication, room-temperature properties, and elevated-temperature properties. Included also are a number of case histories. Amco Sales Div., American Metal Climax Inc., 1270 Avenue of the Americas, New York 20, N. Y.

Circle 542 on Page 19

Limit Switches

Describes Type L oiltight limit switches, including ratings, dimensions, operating data, and mounting variations. Booklet provides suggestions for proper switch applications. Catalog LJ-48, 20 pages. Cutler-Hammer Inc., 328 N. 12th St., Milwaukee 1, Wis.

Circle 543 on Page 19

Recorders, Controllers

Describes single and multipen null-balance recorders and recorder-controllers, also multipoint recorders and multipurpose indicators. Descriptions of typical measurements performed are outlined. Contains information on features, dimensions, specifications, optional accessories, and applications. Bulletin GEA-6887A, 12 pages. General Electric Co., Schenectady 5, N. Y.

Circle 544 on Page 19

Flush Pushbuttons

Oil-Tite flush pushbuttons are described in new booklet, which serves as a guide to control where liquids present a problem. Describes equipment available for flush and surface mounting in standard or custom control stations. Booklet B-7356, 8 pages. Westinghouse Electric Corp., P. O. Box 2099, Pittsburgh 30, Pa.

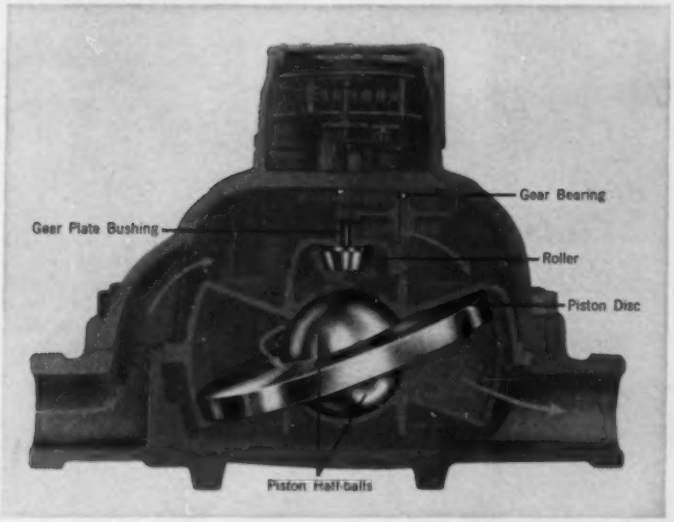
Circle 545 on Page 19

Test Instruments

Short-form catalog describes expanded line of test instruments, miniature magnetic-tape recorders, data-reduction systems, variable-reluctance transducers, and accelerometers. Line of test instruments includes vacuum-tube voltmeters, VSWR indicators, volt-ohm meters, R-F power meters, precision-slotted line instruments, and signal generators. Bulletin CC-861, 4 pages. Borg-Warner Controls, Div., Borg-Warner Corp., 3300 Newport Blvd., Santa Ana, Calif.

Circle 546 on Page 19

Chemical Division 3M COMPANY



KEL-F® BRAND PLASTIC foils corrosive attack, keeps meters on the mark!

Equipment that measures even highly corrosive liquids can be enduringly exact, too! Buffalo Meter Company manufactures meters that measure precisely the flow of over 100 corrosive chemicals, including acetic acid, aluminum nitrate, carbon bisulfide, diethylamine, phosphoric acid, potassium chloride and concentrated sulphuric acid. Vital meter parts—piston discs, half balls and other components, as shown—are made of KEL-F Brand Plastic because it retains its shape and dimension in the presence of corrosive chemicals, even fuming nitric acid.

Other properties which led to the selection of KEL-F Plastic for this application include stability, easy moldability, low cold flow, low specific gravity and good lubricating qualities. The five meter components of KEL-F Plastic are molded for Buffalo Meter Company by Resistoflex Corp., Roseland, N.J., and the Garlock Packing Co., Palmyra, N.Y.

Now, new KEL-F 81 Plastic incorporates many property advantages, along with better-than-ever uniformity and consistency. For more information, read the "profile" to the right, then return the coupon below.

Chemical Division, Dept. KCG-121
3M Company
St. Paul 6, Minn.

TELL ME MORE . . .
about KEL-F 81 Plastic

Name_____

Title_____

Company_____

Address_____

City & State_____

Properties Profile on KEL-F® BRAND 81 PLASTIC

KEL-F 81 Plastic is a fluorocarbon plastic, a thermoplastic resin formed by the homo-polymerization of chlorotrifluoroethylene. The high degree of fluorination of KEL-F 81 Plastic is responsible for its chemical inertness and thermal stability. The inclusion of chlorine in an otherwise carbon-fluorine molecule results in exceptional moldability and mechanical toughness.

Crystallinity. KEL-F 81 Plastic is crystallizable, but not necessarily crystalline, the degree and kind of crystallinity in a given sample being a function of its thermal history. The "quick-quenched" resin is spoken of as amorphous, and the "slow-cooled" resin as crystalline. When crystalline, KEL-F 81 Plastic is a denser, more translucent material with higher tensile modulus, lower elongation, and greater resistance to the penetration of liquids and vapors. The amorphous plastic is less dense, more elastic, with greater optical clarity and toughness.

Physical Properties. The physical properties of KEL-F 81 Plastic combine mechanical, chemical, electrical, and optical advantages. And the most useful applications center around combinations of the following properties:

1. Useful temperature range: from —400° F. to +400° F.
2. Resistance to deformation and flow at high temperatures, pressures
3. Zero moisture absorption
4. Abrasion resistance
5. Radiation resistance
6. Chemical resistance
7. Electrical properties
8. Infrared transmission
9. Inert to liquid oxygen
10. Flexible in contact with cryogenic fuels

Processing. KEL-F 81 Plastic can be processed in the same manner as other thermoplastic resins. Parts of KEL-F 81 Plastic may be specified in any form.

Detailed data on physical properties is contained in a new free brochure. For your copy, return coupon or write to 3M Chemical Division, stating area of interest.

"KEL-F" is a reg. TM of 3M Co.

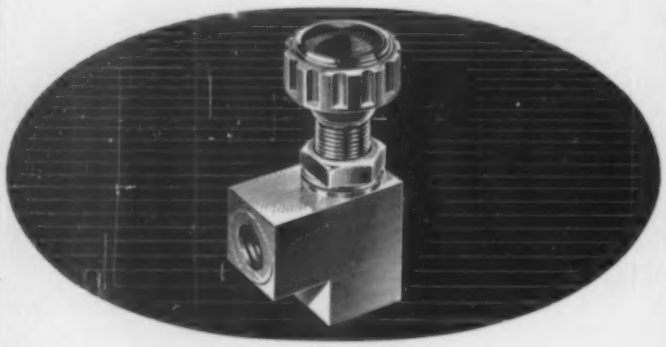
MINNESOTA MINING & MANUFACTURING CO. 3M

Circle 321 on Page 19

PRECISION MADE FOR PERFORMANCE!

ROBBINS VALVES DESIGNED TO SAVE YOU MONEY!

Why let replacement costs and downtime caused by inferior valves ruin your scheduling and waste your money?
ROBBINS VALVES are specifically designed to prevent and eliminate such waste. Design capabilities, test programs, manufacturing procedures, quality control (and even packaging) at Robbins are all directed toward one objective... to produce and offer valves of highest quality that will give you the greatest possible economy and reliability over many years of service.



A FEW OF THE FEATURES OF THAT WILL PROTECT YOUR BUDGET ROBBINS VALVES

* Over 4 to 1 burst factor
* Quality valves that can be completely serviced in less than 1 minute from the front of the mounting panel without removal from the line
* As many as 5000 cycles at full pressure rating before requiring service
* Barrel, spindle, spindle seals, barrel seals and seat in one complete barrel assembly, one unit
* Approved military specification quality control... for both military and civilian valves... meeting or exceeding MIL-Q-5923 and MIL-Q-9858
* All valves LOX cleaned... assembled and packaged to standards recommended by Aero Space Industries Ass'n.
* Shut-off's as low as 1 in-lb. at 1000 PSI... bubble tight
* Minute metering characteristics
* Replaceable soft seat
* Backed by warranty

*Write TODAY for 16-page fully illustrated brochure in color containing complete technical information!

HI-VACUUM TO 12,000 PSI! • OXYGEN HYDRAULIC PNEUMATIC • ANGLE GLOBE THREE-PORT MANIFOLD

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Los Angeles 58, California
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HELPFUL LITERATURE

Nickel-Chrome-Iron

Covers uses and specifications of ABK metal, a nickel-chrome-iron of controlled structure for use in industries where operating conditions produce severe abrasion with little impact. Metal as cast and stress relieved has a hardness of 500/700 Brinell. Gives physical properties as compared with white cast iron. 4 pages. American Manganese Steel Div., American Brake Shoe Co., Chicago Heights, Ill.

Circle 547 on Page 19

Polarizing Systems

Describes Polarite polarizing system for accurate insertion of modular circuit-board assemblies. Illustrates the several types of studs and sockets used in system application. Plugs eliminate the danger of inserting a circuit board in the wrong socket without in any way altering the connectors. Bulletin 6120, 4 pages. Ucinite Co., Div., United-Carr Fastener Corp., Newtonville 60, Mass.

Circle 548 on Page 19

Pressure Indicators

Bulletin and six data sheets cover design, operation, applications, and specifications for Deltadyne pressure and differential-pressure indicators. Gives size, weight, materials of construction, differential-pressure indicating range, and rated system pressure and temperature. 8 pages. Pall Corp., 30 Sea Cliff Ave., Glen Cove, N. Y.

Circle 549 on Page 19

Glass-Fiber-Reinforced Plastics

Provides cost-performance comparison between Fiberglas-reinforced plastics and unreinforced plastics, and between Fiberglas-reinforced plastics and metals. Also offers general properties comparisons of FRP with nylon, low-density polyethylene, general-purpose polystyrene, polyvinyl chloride, low-carbon steel, stainless steel, and cast aluminum. Contains FRP process comparison guide. 40 pages. Write on company letterhead to Dept. 1833, Owens-Corning Fiberglas Corp., 717 Fifth Ave., New York 22, N. Y.

Silicone Potting Compounds

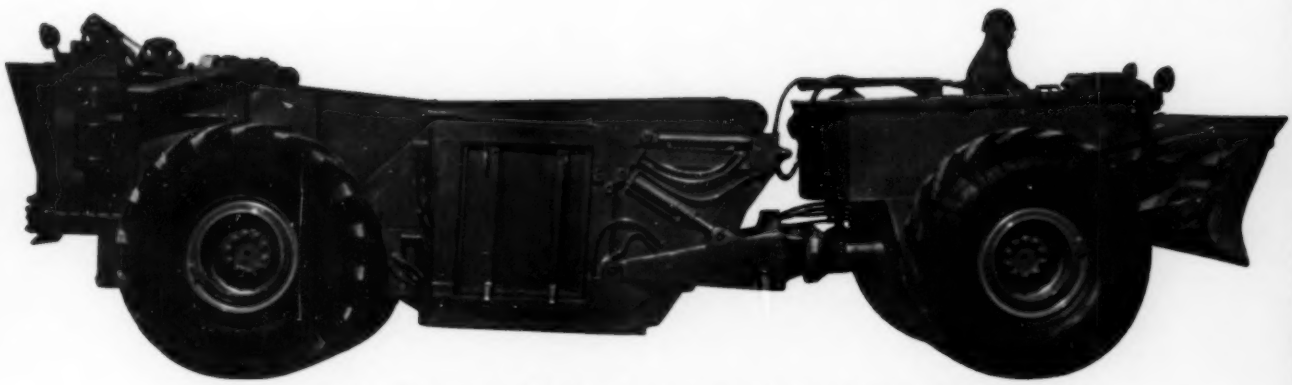
Provides guide to the selection and use of RTV silicone-rubber compounds and transparent, clear silicone potting compound LTV-602. Also covers typical physical and electrical properties. Technical Data Book S-23, 16 pages. Write on company letterhead to Silicone Products Dept., General Electric Co., Waterford, N. Y.

Hydrostatic Transmission

Dynapower hydrostatic transmission systems are described in new bulletin. Applications of the transmission are pointed out, and specifications, performance curves, and dimensions are given. Bulletin DP-2, 4 pages. Write on company letterhead to New York Air Brake Co., Starbuck Ave., Watertown, N. Y.

This mark tells you a product is made of modern, dependable Steel.

it digs
it flies
it swims



Army Universal Engineer Tractor built by Hendrickson Manufacturing Company, Lyons, Illinois. Strength with light weight obtained with use of USS "T-1" Constructional Alloy Steel and USS MAN-TEN High Strength Steel.

and does a dozen other things!

The Universal Engineer Tractor, rubber tired (UET-RT), can do the work of a dozen different machines merely by substituting interchangeable sections. Basically, it is a 250 HP steel tractor-scraper dozer that can be flown in a C-130 Aircraft and parachuted into a combat area, ready to operate. In addition, being sectionalized, it can be quickly disassembled for transport by other types of aircraft.

Although it is lightweight for airborne use, the tractor can transport 10 cubic yards of earth at 35 MPH. It was designed by Barnes & Reinecke, Inc., Chicago engineers, to the requirements of the United States Army Engineer Research and Development Laboratories at Fort Belvoir, Virginia. Three and a half tons of weight were saved by designing the yoke, dozer arms, front and rear axle housings, and basic bowl structure with USS "T-1" Constructional Alloy Steel. "T-1" Steel's minimum yield strength of 100,000 psi permitted working stresses of 60,000 psi.

USS MAN-TEN High Strength Steel with 50,000 psi minimum yield point, in the bowl, side plates and dozer blade saved more weight. The complete unit was built tough and strong with 7,500 pounds of USS "T-1" and MAN-TEN Steels.

For other military vehicles, United States Steel makes extremely tough, rolled armor plate, in addition to a complete line of weldable, formable, high strength and alloy steels. For more information, write United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania. USS, "T-1" and MAN-TEN are registered trademarks.

United States Steel Corporation • Columbia-Geneva Steel Division • National Tube Division Tennessee Coal and Iron Division • United States Steel Supply Division • United States Steel Export Company

USS United States Steel

airborne crane built 500 pounds lighter with USS TRI-TEN High-Strength Low-Alloy Steel

Lightweight crane built strong with USS TRI-TEN High-Strength Low-Alloy Steel. Designed for the U.S. Army Corps of Engineers, Ft. Belvoir, Virginia. Builder: Koehring Co., Milwaukee, Wisconsin.

This air transportable, air droppable U.S. Army crane had to be strong enough to lift 7 tons but light enough to be parachuted into a combat area. The Koehring Company of Milwaukee, Wisconsin, solved the problem with USS TRI-TEN High-Strength Low-Alloy Steel.

By using USS TRI-TEN Steel in the turntable, the lower works of the cruiser, and the boom, Koehring designers used only two tons of steel . . . with a clear saving of 500 pounds. Strength was not sacrificed because USS TRI-TEN Steel has a minimum yield point of 50,000 psi.

USS TRI-TEN Steel is well known as one of the most weldable and toughest high-strength low-alloy steels in the industry. Its superior notch toughness at low temperature makes it ideal for all-weather mobile equipment. TRI-TEN Steel has excellent weldability, good resistance to abrasion, and high atmospheric-corrosion resistance.

For other military vehicles, United States Steel makes extremely tough, rolled alloy armor plate, in addition to a complete line of high strength steels, "T-1" Constructional Alloy Steel, Stainless Steels and carbon steels. For more information, write United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania. USS, "T-1" and TRI-TEN are registered trademarks

United States Steel Corporation • Columbia-Geneva Steel Division • National Tube Division • Tennessee Coal & Iron Division • United States Steel Supply Division • United States Steel Export Company

This mark tells you a product is made of modern, dependable Steel.

USS United States Steel

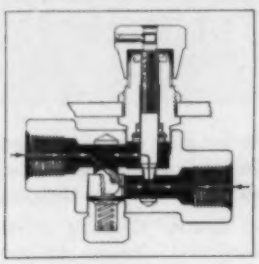
New Parts and Materials

Use Yellow Card, page 19, to obtain more information

Flow-Control Valve

for 5000-psi oil or air-pressure systems

New 1-in. flow-control valve operates at 5000 psi oil or air pressures with a 5 to 1 safety factor. Valve bodies are steel or stainless-steel forgings. Valve incorporates a check valve which permits full flow in one direction, and a contoured needle which provides a wide range of flow adjustments in the opposite, controlled direction. Ball is the only moving part in the flow area. Flow-



control needle adjustments can be made under maximum rated pressure without effort. Three models are available for different mountings. All interior parts of the valve are stainless steel. Valve is available with any of three types of port threads. **Auto-Ponents Inc.**, 3001 Grant St., Bellwood, Ill.

Circle 550 on Page 19

Nylon Zipper

for industrial use is strong, lightweight

Nylon Zip fastener is designed for industrial, military, and consumer-product applications where adverse environmental conditions reduce the effectiveness of metal zippers or render them inoperable. It conforms to nylon zipper standards of Federal Specification V-F-106b. Fastener is strong, lightweight, and

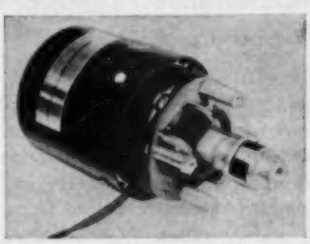
corrosion resistant. It withstands direct heat to 360 F and has a melting point of 480 F. It retains its flexibility and is efficient in temperatures to −70 F. Fasteners are available in 28 different colors, in all lengths, in both separating and nonseparating types. They are manufactured in light, medium, heavy, and extra-heavy chain sizes. Widths range from 0.170 to 0.475 in., tape widths from 7/16 to 1 in. **Slide Fastener Div., Waldes Kohinoor Inc.**, 47-16 Austel Place, Long Island City 1, N. Y.

Circle 551 on Page 19

Motor-Clutch Assembly

has 1/20-hp, 1500-rpm motor

Compact, unitized motor-clutch assembly is now available. Spring-type clutch and solenoid-operated actuator assembly are mounted integral with the shaft and frame, respectively. Start-stop, single-revolution, or fractional-revolution clutches provide a variety of control and indexing functions. A flexible coupling mounted on the clutch-output hub allows some misalignment between



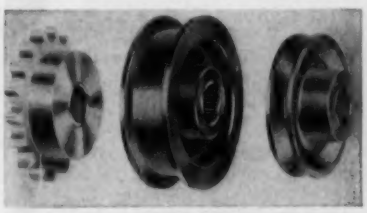
motor-clutch assembly and driven member. Unit has a standard 1/20-hp, 120-v, 60-cycle, 1500-rpm motor. Clutch engagement is controlled remotely by means of the 120-v ac solenoid. **Precision Specialties Inc.**, P. O. Box 118, Pitman, N. J.

Circle 552 on Page 19

Idlers, Tensioner Shafts

in antifriction types

Added to a line of drive tensioners are needle-bearing idlers and hardened and ground tensioner shafts. Antifriction units include 18 sizes of sprockets, V-belt sheaves, and flanged, flat-face pulleys, all with 1-in. bore. Hardened and ground shafts are available in 2, 3, and



4-in. lengths. **Brewer Machine & Gear Co.**, 1441-43 N. Second St., St. Louis 6, Mo.

Circle 553 on Page 19

Waterless Decals

have one or two-side imprints

Dri-Appli decals are true, lacquer-base materials. Consisting of a facing sheet, decal, and backing sheet, they save time and go into position more accurately than water-applied decals. Application consists of removing the facing sheet, locating correct decal position by use of center guides printed on the backing sheet, applying pressure to the decal area, and stripping the backing sheet. Backing sheet provides a pro-

UNIFORM TUBING
always available

FAST DELIVERY

ALLOYS
Almost any analysis, including aluminum alloys—1100, 3003, high purity, 2024, 5052, 6061, 6951 and the new high strength alloy UT58; copper alloys—OFHC Copper, Phosphor Copper, 70/30 Brass, Yellow Brass, Red Brass, 18% Nickel Silver, "A" Phosphor Bronze, #25 Beryllium Copper, 30% Cupro Nickel; Nickel alloys—"A" Nickel, Monel, Inconel, 220 Nickel; 300 Series Stainless Steels; Glass-to-Metal Sealing alloys; Precious Metals; Columbium and Tantalum.

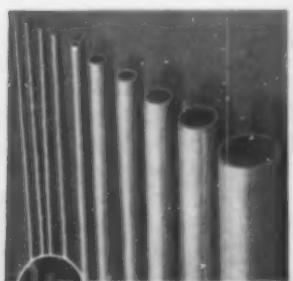
SIZES
O.D. from .625" to .005". Wall thicknesses down to 0.0005".

TOLERANCES
Commercial or precision—down to ±0.00005" on special application.

FABRICATION
Have your tubular parts "made at the mill"—by skilled tubing fabricators, specializing in burr-free, close-tolerance cutting, bending and flaring.

A complete fabrication service cuts subcontracting costs, concentrates responsibility, ensures better delivery and better parts, ready for assembly.

Phone or wire your requirements.



UNIFORM TUBES, INC. COLLEGEVILLE 2, PA
HUxley 9-7276 TWX-CGVL 1044

Circle 323 on Page 19

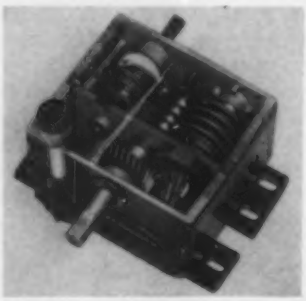
tective mask which can remain in place during production, painting, inspection, and shipping. Decals can be mounted on opaque surfaces, on front or back of transparent surfaces, and can have one-side or two-side imprints. **Allied Decals Inc.**, 20700 Miles Ave., Cleveland 28, Ohio.

Circle 554 on Page 19

Adjustable-Speed Drives

incorporate new helical steel gears

Helical steel gears replace steel spur gears in gearhead models of fractional-horsepower, adjustable-speed drives in 3 to 150 lb-in. torque output range. Gears are high-carbon steel, providing smooth, strong, quiet



performance. Gearheads either increase torque while reducing the speed range or increase the speed range with a resulting reduction in torque. Speed ranges go from 80-0-80 rpm to 1200-0-1200 rpm in gearhead models. Helix angle of 21 deg, 2 min insures constant meshing at pressure angles of 20 deg. Gearhead is mounted to the drive in a die-cast case which houses both gearhead and drive mechanism. They are lubricated in common. **Zero-Max Co.**, 2845 Harriet Ave. S., Minneapolis 8, Minn.

Circle 555 on Page 19

Microminiature Potentiometer

for panel applications

Model MS-7 ¼-in. diam potentiometer is designed for panel applications where microminiature size and extreme environmental performance are desired. Specifications include standard resistance values from 100 to 10,000 ohms, ¼-w dissipation,

LOOK BEFORE YOU LEAP..

and you will SPECIFY THOMAS FLEXIBLE COUPLINGS

It is just plain common sense to "Look before you leap" when selecting a flexible coupling.

An inferior coupling causes wear and damage to your machines — resulting in high maintenance costs and costly shut-downs.

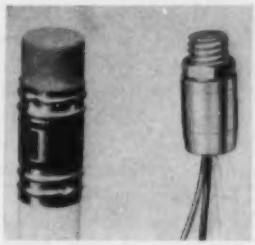
Troublesome maintenance problems are eliminated when you specify Thomas "All-Metal" Flexible Couplings to protect your equipment and extend the life of your machines.

NO MAINTENANCE
NO LUBRICATION
NO WEARING PARTS
NO BACKLASH

Write for Our New Engineering Catalog 60

THOMAS FLEXIBLE COUPLING CO.
WARREN, PENNSYLVANIA, U.S.A.

Circle 324 on Page 19



weight of 0.03 oz, Teflon-insulated leads, and an anodized-aluminum housing. Unit operates in temperatures from −55 to +150 C. **Miniature Electronic Components Corp.**, Holbrook, Mass.

Circle 556 on Page 19

External Wrenching Bolt

180,000-psi unit meets new military specification

High-fatigue tension bolt meets specification MIL-B-8831, the first to be issued by the military covering a 180,000-psi tension bolt. The 12-point external wrenching bolt, designated MS 21250, is a high-fatigue version of the EWB 18 bolt. It uses MIL-S-8879 thread form; which has a controlled, large-radius thread root. Fatigue strength of the bolt is rated at 45,000 cycles minimum, 65,000 cycles average at an alternating load of 93,000 psi maximum, based on minimum minor thread area. Mating lightweight lock nuts are furnished in ¼ to 1½-in.

diam. **Standard Pressed Steel Co.**, Jenkintown, Pa.

Circle 557 on Page 19

Ball Valves

for pressures to 1000 psig

McCannaflo ball valves are available with pneumatic and electric operators for automatic and remote on-off flow-control applications. Both types of operators are sold integrally with the valve or separately

Have you checked carbon & graphite's MANY

"MECHANICAL ADVANTAGES" LATELY?

for High Temperature Work—As bearings or seal rings, several specially-formulated Stackpole grades provide long life and low friction up to 1200°F—temperatures where more costly and exotic materials often fail.

for High-Speed, Unlubricated Uses—In terms of life, maximum speed, and low friction, Stackpole carbon & graphite offer many performance dividends over even more costly self-lubricating bearing and seal ring materials.

Handling Chemicals & Gases—Inert Stackpole carbon & graphite resist attack in all but the most highly oxidizing atmospheres at normal temperatures.

Under Thermal Shock—Stackpole carbon and graphite materials will not spall, crack, melt or seize in difficult refractory applications.

STACKPOLE

Stackpole Carbon Company, St. Marys, Pennsylvania

GRAPHITE BEARINGS & SEAL RINGS • ROCKET NOZZLES • PUMP VANES • VOLTAGE REGULATOR DISCS • GRAPHITE HEATING ELEMENTS • CHEMICAL ANODES • BRUSHES FOR ALL ROTATING ELECTRICAL EQUIPMENT • ELECTRICAL CONTACTS • CERAMIC MAGNETS • FERRITE CORES FIXED & VARIABLE COMPOSITION RESISTORS • SLIDES SWITCHES • and many others.

Circle 325 on Page 19

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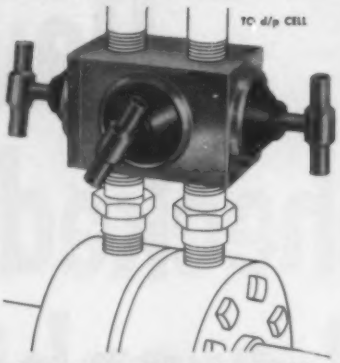
LOW COST VALVE MANIFOLDS ELIMINATE BY-PASS VALVES, FITTINGS, PIPING!



Dahl DEMI Miniature Packless Valves offer great porting versatility in isolating, routing and by-pass applications. For example... three-way manifold, used across a flow metering, differential sensing device allows it to be zeroed or isolated from line for test . . . reducing size and cost of installation.

Patented basic design offered in forty-three styles . . . with metal-to-metal seating, TEFLON seats, or neoprene diaphragms . . . all featuring bubble tight shut-off.

Low cost "DEMI G" valves, in ⅛" to ½" N.P.T. sizes, provide positive control in minimum space. Many actuating devices. Wide selection of construction materials.

REQUEST free 32-page Catalog D-1 for complete details. G. W. Dahl Co., Inc., 83 Tupelo St., Bristol, R. I.

G. W. DAHL CO., INC.

SPECIALISTS IN COMPACT VALVES AND CONTROLS

G. W. DAHL • G. W. DAHL • G. W. DAHL • G. W. DAHL • G. W. DAHL

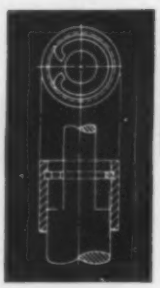
Circle 326 on Page 19

...Improve Product Quality!
...Lower Production Costs!

NATIONAL RETAINING RINGS

Call or write for catalog or ask for recommendations on specific applications

Eliminate machining time and material waste resulting from cutting down shafts and housings to form shoulders. Using smaller shafts, grooved to accommodate economical NATIONAL Retaining Rings, accomplishes important cost reductions, speeds-up production, actually improves the product. Proven applications range from heavy duty machinery to small tools, electronic instruments and toys.



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MILWAUKEE 2, WISCONSIN
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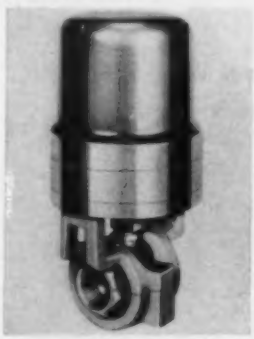
Serving Industry Since 1886

Circle 327 on Page 19

for valves already in service. Pneumatic operators are available in three sizes. Operators mount directly on the valve to simplify alignment and reduce space requirements. Electric operators are of weatherproof and explosionproof construction. They have stainless-steel output shaft, aluminum housing and hardened-steel gear train. Operators are clamp-mounted directly to the valve body. Cycle times as short as 5 sec from full open to full close are possible, depending on valve size. Power required is 115 volt ac. Ball valves are available in sizes



from ¼ through 2 in. for pressures to 1000 psig and temperatures to 550 F. **Hills-McCanna Co.**, 400 Maple Ave., Carpentersville, Ill.

Circle 558 on Page 19

DC Timing Motor

eliminates cogging action

Series 43100 dc timing motor has a permanent magnet enclosed by a nonferrous rotor cage and windings, providing stabilizing eddy-current effect which minimizes speed changes due to applied loading and temperature variations. Assembly also eliminates pre-established poles which cause cogging action usually found in dc motors. The 6-oz motor is designed for commercial and industrial applications where dc generator or battery power are required. Motor and gear train are enclosed to provide protection in adverse environments. Designed to operate in temperatures from −4 to +160 F, motor is vibration and shock resistant. It is supplied with windings for 5, 12, or 27½ v dc standard, and has 150 different output speeds from 2700 rpm to ½

rph, depending on voltage and winding. Various types of gear trains are available. **A. W. Haydon Co.**, 232 N. Elm St., Waterbury 20, Conn.

Circle 559 on Page 19

Thermoplastic Resin

is medium-impact type

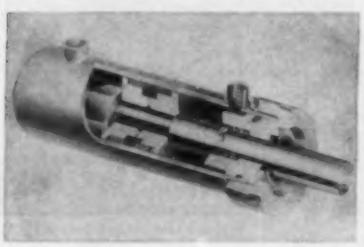
Cycolon medium-impact thermoplastic resin has general ABS physical properties but not the high impact performance of Cycolac-brand polymers. Major processing properties include high gloss, fast mold cycling and flow, excellent sheet forming, good profile dimensional control, and high extrusion rates. Product is recommended for sheet extrusion and injection molding. Applications include refrigerator trays and crispers, automotive duct work, knobs, and grills, toys, advertising display racks, phonograph records, seats, housewares, and radio and television components. Standard, natural, or custom colors are available. **Marbon Chemical Div., Borg-Warner Corp.**, Washington, W. Va.

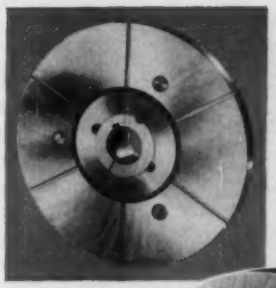
Circle 560 on Page 19

Hydraulic Cylinder

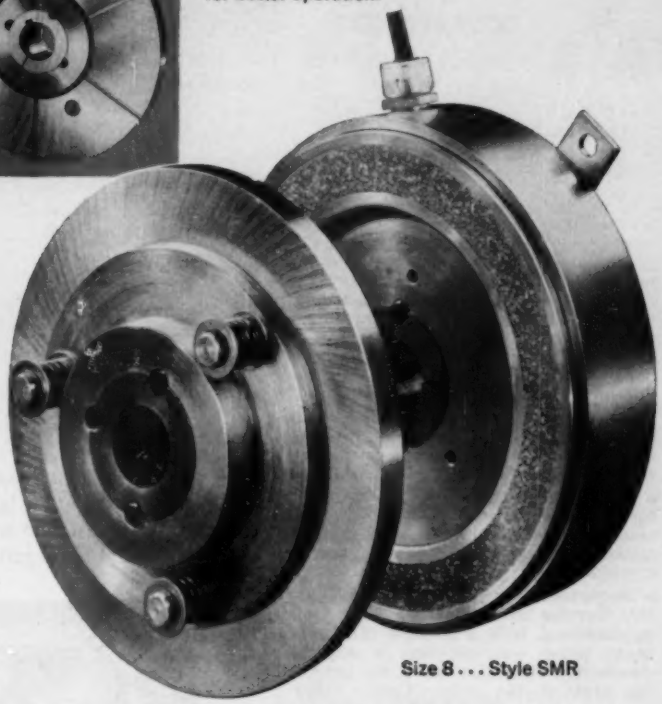
has spring-locked packing

Series 700 heavy-duty hydraulic cylinder incorporates a spring-lock action which automatically maintains constant preload between packing and rod, preventing fluid





Grooved armature dissipates heat . . . provides wiping action for better operation.



Size 8 . . . Style SMR

STEARNS New 8-in. dia. Electro-Magnetic Clutch Packs 1740 lb-in. Torque

Application of this new Stearns clutch is simplified by the remarkably high torque-to-size ratio. Ball bearing-mounted stationary magnet body eliminates slip rings. New spring release armature provides positive disengagement. Completely encapsulated coil and solid armature assure dependability, whatever the application — packaging machinery, textile machinery, machine tools, etc.

Stearns offers you the largest selection of competitively priced stationary magnet clutches on the market today — nine sizes in all, from 2 to 1740 lb-in (145 lb-ft) torque. Stearns SMR clutches are available for all standard DC voltages to 90 volts — class A through H insulation — with integral sprockets or sheaves in split and thru-shaft arrangements. Also available as a flange-mounted brake.

Rely on Stearns, pace-setting pioneer since 1917, for all your electro-magnetic clutch, brake and clutch-brake requirements. Write for Clutch Data File NPP 12-61C.

Stocked by authorized distributors in all principal cities

Stearns
ELECTRIC CORPORATION
120 N. BROADWAY, MILWAUKEE 2, WIS.

Circle 328 on Page 19

PUMP DESIGN TRENDS

ARTHUR A. NICHOLS

SPECIAL PURPOSE PUMPS FOR SPECIAL PROBLEMS

► In over thirty years experience in the design and manufacture of special pumps, we have solved numerous pumping problems where the design and production of a suitable pump was considered almost impossible, either because of the material to be pumped, or because of the precise manufacture necessary to obtain satisfactory performance.

► **Nichols pumps are standard for example, in the synthetic fibre industry for pumping rayon, acetate, celanese, nylon and other fibres spun in synthetic fibre plants throughout the world.**

► Some interesting new applications for Gerotor pumps have been developed in recent times involving specialized problems in hydraulic servo systems.

► **Important advantages are offered by the Gerotor pump for servo control applications. It is a positive displacement pump and provides a smooth power flow from one end of the pumping cycle to the other. Unlike other types of pumps which tend to quit work at the low end of the speed range,** *Gerotors stay right on the job and provide positive power to the extremely low range.* **Thus, they are exceptionally responsive in servo systems.**

► For electronic equipment operating at high altitudes, air cooling of high input components becomes troublesome because lower air density limits cooling fan efficiency. Liquid cooling systems are therefore frequently preferred for this type of service. Our extensive experience over the years in the production of high performance aircraft engine pumps has been of great value in developing electronic coolant circulators that provide maximum weight and space savings with efficient heat transfer capabilities.

► **Special pumps have been designed and manufactured for applications as varied as metering pumps in vending machines and conveying molten solder in production equipment. This long and varied experience in industry-wide pumping applications, combined with years of specialized development and production of pumps for the aircraft engine, super-charger, missile, helicopter and electronic field is available to today's designer faced with new and unusual pumping applications and problems.**

► *Technical data is available and your inquiry is invited. Write:*

W. H. NICHOLS CO.

Makers of Zenith Metering Pumps and the Nichols Milling Machine "the miller that uses its head".

48 WOERD AVE., WALTHAM 54, MASS.

Circle 329 on Page 19

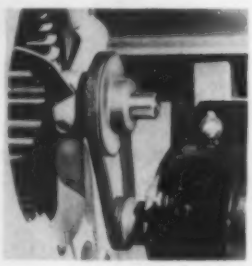
leakage resulting from worn packing. Cylinder is equipped with self-contained wiper, aircraft-type, self-locking retainer nut, all-steel piston and stuffing-box components, and phenolic bearing and adaptors which prevent metal contact with cylinder wall. **Ward Hydronics Inc.**, 11600 Genesee St., Alden, N. Y.

Circle 561 on Page 19

Belt Drive

saves space and cuts noise

Increased surface contact with the sheave in Poly-V J-belt drive design permits belt to transmit more horsepower in less space with lower face pressures. Unit also reduces the noise and vibration level. Illustrated is a belt installed on an overhead air-conditioning unit. The ⅛-



hp motor operates at 1300 rpm. Drive belt is ⅜ in. wide; driver sheave is 1.5 in. wide and driven sheave is 2.8 in. Poly-V drives for large, medium, and small-capacity drives are available. **Manhattan Rubber Div., Raybestos-Manhattan Inc.**, Passaic, N. J.

Circle 562 on Page 19

DC Accelerometer

is small unit for industrial applications

Model No. 24124 accelerometer features low natural frequency and high resolution in a small, lightweight unit. Originally designed for telemetering and flight control of missiles and aircraft, it is now suitable for industrial applications. Accelerometer is fluid-damped and hermetically sealed. Specifications include a linearity of ±1.0 per cent, hysteresis of ±0.5 per cent, with a repeatability of ±0.5 per cent and resistance measurement of 2000 to

COMPLETE SLIP RING ASSEMBLIES

Standard and Custom-Built

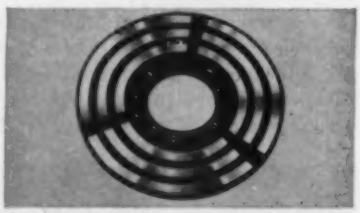
...by SCP

NO. SK-1334 STANDARDIZED CYLINDRICAL ASSEMBLY 15 TO 30 CIRCUITS

Diameter overall.....4½"
Height overall.....8¾"
Capacity.....2 amps, 250 v, 60 cy
R. P. M.....up to 1200

Stock delivery.

All phases of design and manufacture of slip ring assemblies are handled by the Superior staffs. All contact grades, plastic formulae, metallurgy, machining and assembly, pilot runs, and other steps are under the close scrutiny of highly trained personnel. Superior was the first to deliver the "complete package": engineering, contact and holder assembly, ring and complete final test of entire units. From Superior Carbon Products, you buy an unparalleled background in the field of slip ring assembly design and manufacture.

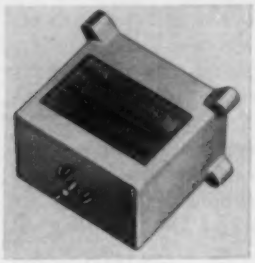


The second basic type, a pancake ring assembly, with segmented rings of varying diameters.

SUPERIOR CARBON PRODUCTS, INC.

9115 George Avenue • Cleveland 5, Ohio

Circle 330 on Page 19



5000 ohms. Standard units can be modified to provide a switch output, plug-in connectors, other ranges, and a variety of mounting configurations. **Giannini Controls Corp.**, 1600 S. Mountain Ave., Duarte, Calif.

Circle 563 on Page 19

Insulating Gaskets

for ASA flanges

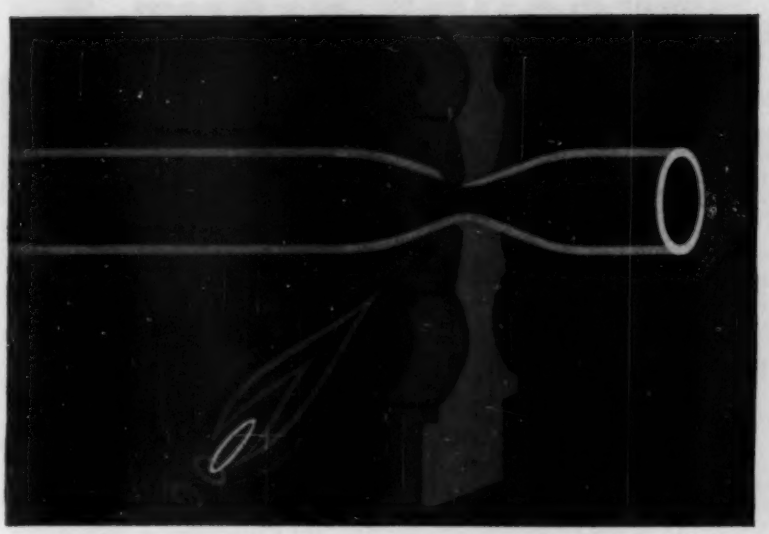
Series 6500 gaskets combine insulating material with controlled confinement principle of the Gask-O-Seal. Principle allows full metal-to-metal contact of faying surfaces and prevents crushing of the seal itself. Seals cannot cold-flow or be squeezed out by pressure. Need for high fastening torques is eliminated, and Gask-O-Seals are reuseable. They are particularly useful in high-pressure systems. By combining the insulating design with the Gask-O-Seal principle, no-leak sealing is obtained, in addition to insulation. **Parker Seal Co.**, 10567 W. Jefferson Blvd., Culver City, Calif.

Circle 564 on Page 19

Antifriction Screw

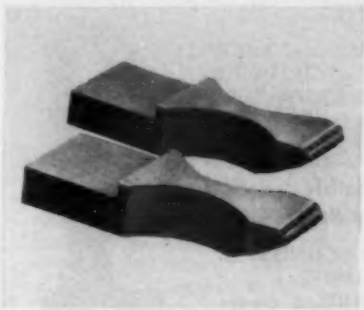
is nonrecirculating-type unit

Improved antifriction screw features no heat treating. It offers greater strength than earlier heat-treated screw by providing an increase in tensile strength and yield point. It



What wears out in your plant?

Where resistance to high heat is a requisite, Kentanium* heat-resistant titanium carbide alloys are ideal engineering materials. For they can operate continuously at temperatures up to 2200°F and at even higher temperatures under specific conditions.



PRODUCE 215,000 UNITS COMPARED TO 25,000. Kentanium pinch jaws solve a glass tubing pinch-off and vacuum sealing problem in production of sealed beam lamps by operating in a 1700°F flame to heat withdrawal tube—and by averaging 215,000 units as compared to 25,000 for steel jaws.

Kentanium's high strength and resistance to oxidation at high temperatures has greatly extended its field of usefulness. Other unique properties include high resistance to thermal shock, abrasion, deformation, and its high stiffness-to-weight ratio—the highest of any known material.

Some typical applications are hot rod mill guide inserts, flame burner tips, high temperature thermostat sensing elements, ball and seat valves, jet engine shaft seal rings and inserts for machining high temperature alloys at high velocity.

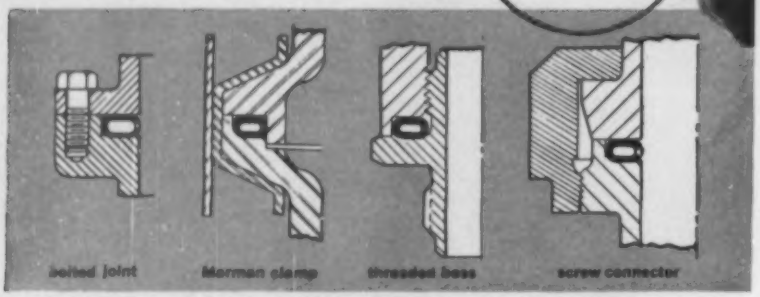
The outstanding properties of Kentanium, plus our research and development facilities are helping to translate ideas into products that combine reliability with long service. You may find profitable uses of Kentanium carbides in your plant.

For additional information about Kentanium, write for Booklet B-444. KENNAMETAL INC., Dept. MD, Latrobe, Pennsylvania. *Trademark 30631

KENNAMETAL Inc.

Circle 331 on Page 19

PRESSURE-TIGHT JOINTS 10^{-6} mm Hg-100,000 psi



United Self-Energized Metallic O-Rings*...

form positive, permanent, non-corrosive, static seals under pressure extremes from 10^{-6} mm Hg to 100,000 psi (or the ultimate compression stress of the metal itself) and temperatures from −452° to 3000° F. Available in various metals and coatings (including Teflon** and silver) ¼" O.D. to any size and configuration. United also makes non-vented and pressure-filled O-rings.

United Metallic "O" Rings, manufactured by United Aircraft Products, Inc., Box 1035, Dayton, Ohio.

See United Metallic O-Ring Catalog in Sweet's Product Design File or write for Free Handbook

*Patents 2,809,269; 2,837,360
**DuPont registered trademark

Circle 332 on Page 19

Wolverine TOGGLE CLAMPS
Cost Less per Thousand Clamping Operations

Note These Important Features:

- HARDENED PINS and BUSHINGS
- HEAVY BODY SECTIONS
- BLACK OXIDE FINISH
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Circle 333 on Page 19

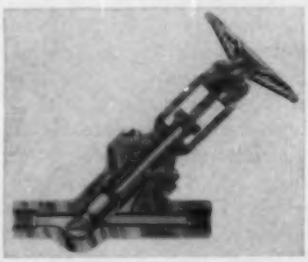
has four threads per inch and holds any elevated load without slipping or counter-rotating. It offers pitch accuracy of 0.001 in. per 1 in. of travel. Screw has a case-hardened, nonrecirculating ball nut which prevents counter-rotating of the screw. Dimensions of the screw are ¾ in. diam and 18½ in. long. **R. C. S. Tool Co.**, 13861 Vanowen St., Van Nuys, Calif.

Circle 565 on Page 19

Flow-Control Valves

in new superhard alloy

Arrowflo straight flow-control valves have bodies, seats, and stem tips made of an alloy with a hardness rating of Rockwell C 67-70. In addition to high hardness, alloy has a tensile strength of over 70,000 psi and is more corrosion resistant than carbon steel. Seat arrangement in



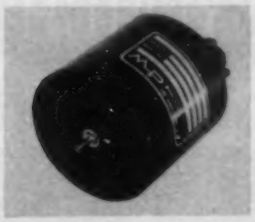
the valves also contributes to long wear, seat being parallel to the line of flow and removed from the impingement of the flowing medium. Ground face on the seat and tip gives positive shutoff. Valves are availible in standard sizes and pressure ratings. **Flow Systems Inc.**, 842 Production Place, Newport Beach, Calif.

Circle 566 on Page 19

Stepping Motor

takes "add" and "subtract" pulses

Shaft of stepping motor Model 611 turns 9 deg (40 steps per revolution) each time an electrical step signal is applied. "Add" pulses step the shaft clockwise and "subtract" pulses counterclockwise. No-load position error per step is ± 0.5 deg non-cumulative. Rotor inertia is 0.012 oz-in.^{2} with maximum load in-



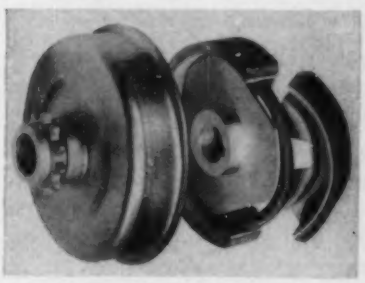
ertia of 0.12 oz-in². Frequency range is 0 to 6000 cps. Unit provides instant reversibility and reliable operation from 0 to 9000 rpm. U. S. Science Corp., 5221 W. 102nd St., Los Angeles 45, Calif.

Circle 567 on Page 19

Heavy-Duty Clutch

engages smoothly at low rpm ranges

New Comet 4-in. clutch, available for electric motors and four-cycle engines (chain and V-belt), is a lightweight, heavy-duty model which engages smoothly, under load, at low rpm ranges. With a close-to-engine sprocket, greatest power is transmitted with the least stress. Sprocket is close to the center of the bearing, which distributes the load evenly. Internal spring permits full-width friction contact around the entire circumference. Unit is fade-proof and chatterproof. It is available with various pulleys, sprockets,



and bores. **Comet Industries**, 801 Elm Place, Richmond, Ind.

Circle 568 on Page 19

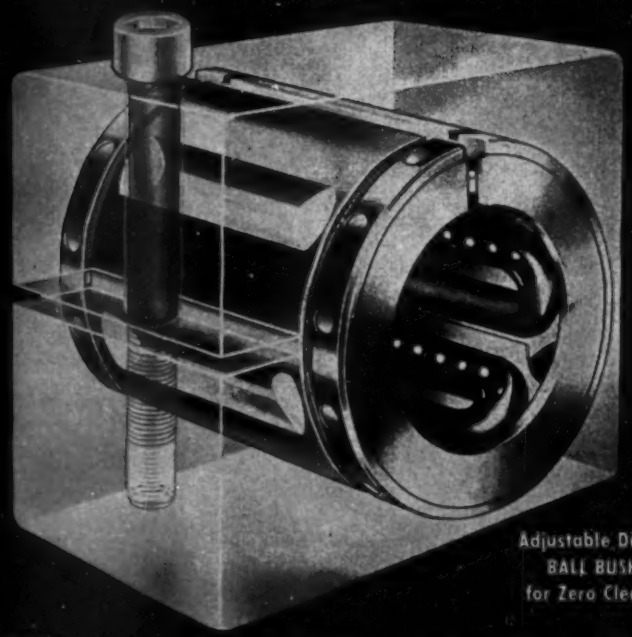
Float-Valve Assemblies

operate horizontally vertically in small space

Models RM 116 and 117 miniature floa-valve assemblies provide accurate control of water lines in beverage-vending and ice-making machines, room and furnace humidi-

NOW! *Adjustable Diameter and Open* THOMSON

BALL BUSHINGS



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Open BALL BUSHING for Zero Clearance on Supported Shafts

Sliding linear motions are nearly always troublesome. Thousands of progressive engineers and designers have solved this problem by application of BALL BUSHINGS on *guide rods, reciprocating shafts, push-pull actions,* or for support of *any mechanism that is moved or shifted in a straight line.*

Improve your product! Up-date your design and performance with Thomson BALL BUSHINGS!

LOW FRICTION · ZERO SHAKE OR PLAY
ELIMINATE BINDING AND CHATTER
SOLVE SLIDING LUBRICATION PROBLEMS
· LONG LIFE · LASTING ALIGNMENT

The various types cover a shaft diameter range of ⅛" to 4". Small sizes available in Stainless Steel. Write for literature and name of our representative in your city.

THOMSON INDUSTRIES, Inc.
Dept. E, MANHASSET, NEW YORK

Circle 334 on Page 19

Also Manufacturers of NYLINED Bearings . . . Sleeve Bearings of DuPont Nylon, and 60 CASE . . . Hardened and Ground Steel Shafting

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TO ATOMIC STEAM GENERATING EQUIPMENT

Here's versatility at its peak . . . in Vulcan's wide range of electric immersion heaters for industry, commerce and home. They range all the way from 100 to 500,000 watts in standard voltages. Units are readily adaptable to thermostatic control. Moisture-proof, dust-proof or explosive-proof construction is available. Heaters are designed for all types of fluids . . . water, oil, steam, air, Dowtherm, etc. And they're also available as packaged units, complete with shells and jackets.

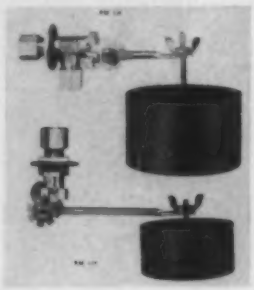
Write for Catalog VG-201.

VULCAN

Versatility in Electric Heating

VULCAN ELECTRIC COMPANY, Danvers, Mass.

Circle 335 on Page 19



fiers, and other equipment having highly restricted dimensions. Valves operate both horizontally and vertically. Design permits accurate water shut off with minimum float size and arm length, and permits wide variations in the location of the valve inlet in relation to the desired water line. Both models feature stainless-steel seat, neoprene disc, and brass body, plunger, arm, and stem. Floats, available in several sizes, are of nontoxic, hard, cellular rubber. They can be used at temperatures to 250 F. Robert Mfg. Co., 9035 Venice Blvd., Los Angeles 34, Calif.

Circle 569 on Page 19

Antifriction Tape

is nontoxic, noncontaminating

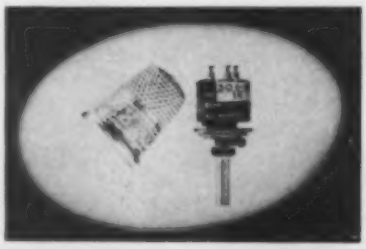
Permacel 424 antifriction, Class H pressure-sensitive Teflon tape has a 10-mil backing of Teflon and electrical-grade silicone adhesive. It is nontoxic and noncontaminating, and has high heat resistance. Permacel, New Brunswick, N. J.

Circle 570 on Page 19

Rotary Potentiometer

has standard linearity of 0.3 to 3.0 per cent

Series 304 subminiature rotary potentiometer, weighing 7 grams and with a total over-all case length of ⅜ in., is a single-turn unit with



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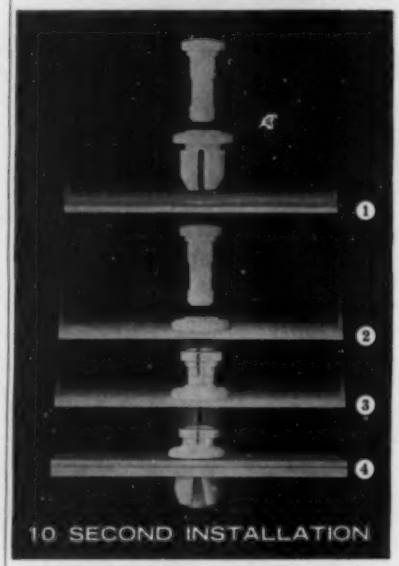
LATCHES FOR INDUSTRY



① PUNCH A STANDARD HOLE.
② PUSH IN GROMMET — CAPTIVATED!
③ PUSH IN PLUNGER — CAPTIVATED!
④ PUSH TO LATCH — PULL TO UNLATCH.

Nylatch is a positive interference type fastener . . . thoroughly tested for rugged, dependable service. It will not unfasten under the severest conditions of impact or vibration, yet may easily be opened and closed 30,000 times without appreciable loss of holding power.

Nylatch is being used to replace all manner of latches, captive screws, stud fasteners and spring clips.

Here are only a few of the hundreds of different uses for Nylatch: Electronic chassis; securing printed circuits; luggage; access doors; any type of removable panels; cabinets; neon signs; tool kits; and many more.

Perhaps one of these uses reminds you of an application that will help you cut costs.

Various head configurations are available; the easy-grip, the mini-grip and the tamper-proof shown above.

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Circle 336 on Page 19

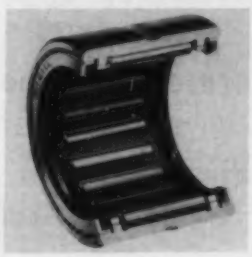
high linearity. Standard is 0.3 to 3.0 per cent with linearities as fine as 0.18 per cent available on special order. Series meets or exceeds all applicable MIL Specs, carrying 2 w of 50 C in still air, and operating from −55 to +125 C. Resistance values range from 10 ohms to 50 kilohms. Circular design of the mandrel permits use of a long resistance winding, affording high resistance values. **Potentiometer Div., Daystrom Inc., Archbald, Pa.**

Circle 571 on Page 19

Roller Bearings

are sealed cage-type units

Cagerol sealed cage-type roller bearings are prelubricated, and integral seals avoid extra bearing width required for auxiliary seals. Seals protect the inner components of the bearing from contamination and retain lubricant to reduce the frequency of relubrication. Retainer design controls roller alignment under speed and shaft misalignment conditions that are beyond the capabilities of ordinary end-guided needle roller bearings. Series is furnished with or without separable inner races. Seals are functionally equivalent to standard commercial lip-type seals. Five different seal combinations are possible. Bearings are available from stock in shaft sizes from 0.625 in. They are dimensionally interchangeable with ordinary needle roller bearings. **McGill Mfg. Co. Inc., Valparaiso, Ind.**



Circle 572 on Page 19

Plastic Piping

for low-pressure use

Beetle plastic piping is for corrosion-resistant piping in low-pressure (to

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for tubing • piping • conduits • wire bundles • support of equipment and instruments.

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- Weight saving
- Awkward shapes
- A minimum of drilling in structural material is desirable, "The Swiss Cheese Effect"
- When to use special types
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Address _____

Firm _____

Engineer_____ Student_____ Other_____

Circle 338 on Page 19

50 psi) supply and drain lines. Light in weight, it is easy to handle, reducing the problems of hangers or supports. Piping resists practically all acids and is resistant to solvents and alkalis. Pipe features Weband joint which provides simple, low-cost installation. Piping eliminates galvanic action and does not require paint or other care. **Carl N. Beetle Plastics Corp.**, 198 Airport Rd., Fall River, Mass.

Circle 573 on Page 19

Mylar Polyester Film

has dielectric strength of 25 kv ac

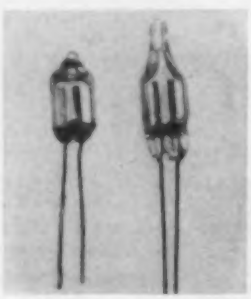
New 14-mil Mylar polyester film provides a heavy, rigid material for electrical insulation and materials-surfacing applications. Typical property values are: Dielectric strength, 25 kv ac; dielectric constant at 1000 cps, 3.3; dissipation factor at 1000 cps, 0.0052; tensile strength, 20,000 psi; elongation, 200-250 per cent; melting point, 245-260 C. E. I. du Pont de Nemours & Co., Wilmington, Del.

Circle 574 on Page 19

Glow Lamps

have glass length of ½ in. and bulb diam of 0.244 in.

Two small glow lamps, known as the A1B (in standard brightness) and A1C (in high brightness), have a maximum over-all glass length of



. . . spells out the answer to your sealing problems

D ecreases maintenance expense

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A djusts itself automatically

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L essens power costs

For free engineering counsel on your sealing problems . . . write

The PERFECT SEAL

DURAMETALLIC CORPORATION
KALAMAZOO, MICHIGAN

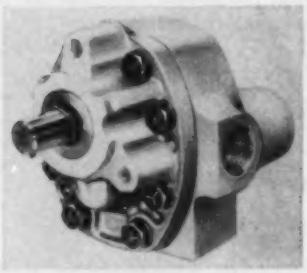
Circle 339 on Page 19

½ in. and a maximum bulb diameter of 0.244 in. They are ¼ in. shorter than other GE glow lamps, but are roughly equivalent in brightness. Lamps are also available with attached resistors. Electrodes are full 5-mm length used in the larger-sized NE-2B glow lamps. New lamp has a formed tip and allows electrodes to be used in the smaller-sized bulb. **Miniature Lamp Dept., General Electric Co.,** Nela Park, Cleveland 12, Ohio.

Circle 575 on Page 19

Hydraulic Pumps

in many variations and types



Types P005 and P007 hydraulic pumps (shown) are typical in a line of 144 variations from one basic spur-gear hydraulic pump. Performance range is from 2 to 100 gpm at 2000 psi and 2000 rpm. P005, which pumps more than 5 gpm at 2000 psi and 2000 rpm, is converted to a P007, with a flow more than 7 gpm, by changing only internal gears and bearings. Without changing the basic configuration, pumps have side ports (shown) or end ports; spline, keyed (shown), or special drive shafts; plain or roller bearings; clockwise or counterclockwise rotation. Envelope dimensions of the pump shown are 5⅝ in. long (including drive shaft), 4½ in. wide, and 4¼ in. high. The all-aluminum pump weighs 5½ lb. **Romec Industrial Div., Lear Inc.,** 241 S. Abbe Rd., Elyria, Ohio.

Circle 576 on Page 19

Subminiature Switch

for precision, low-resistance uses

Model 710 high-current, subminiature switch has snap action pro-

NEW BLH MICROMINIATURE AMPLIFIER IS SMALLEST, MOST RELIABLE UNIT AVAILABLE AT ITS PERFORMANCE LEVEL

Top Performance in Miniature... less than one cubic inch of:

Power—gains of 10, 20 and 200, with other gain values available.

Stability—better than ±15 microvolts referred to the input and to a given temperature, including all effects of use and environment..

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Linearity—terminal linearity better than ±.05% of full scale.

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See for yourself the unlimited possibilities this tiny new amplifier offers. For complete specifications on the Model 700 Amplifier write us or contact one of the 17 BLH sales engineering representatives throughout the U.S. and in Canada.

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FIRST in force measurement

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Circle 340 on Page 19

AJAX ability to handle angular and offset misalignment totaling 7 degrees and more is preventing breakdowns, relaxing production tolerances, cutting assembly and maintenance costs. *Write for catalog.*

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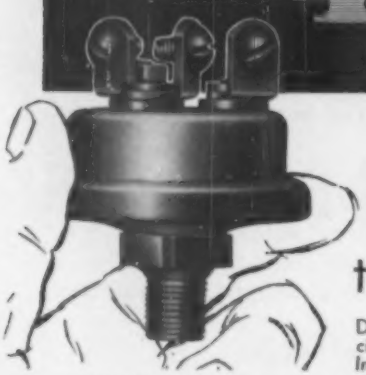
Circle 341 on Page 19



Hobbs DUAL CIRCUIT PRESSURE SWITCHES

Add a NEW DIMENSION to Pressure Activation!

DOUBLE DUTY! Disconnects one electrical circuit while placing the other in operation. *Industry-approved for a wide range of applications in dual circuit activation of various types of instruments, warning signals, safety devices, fuel pumps — in many other ways for making and breaking circuits. Ideal for locking out a starting motor while the engine is running. Can be used with oil or air . . . or with standpipe, almost any liquid or gas.*

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Available in pound setting specifications in both circuits within ranges of 3-6, 7-14 and 15-60 psi. Compact — only 1-11/16" diameter. Pressure assembled and pre-tested at 150 psi. Designed for use on direct current.

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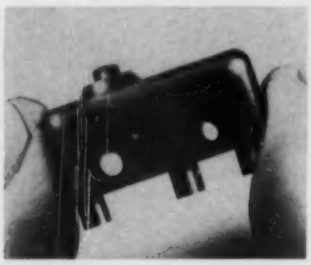
2081 YALE BLVD., SPRINGFIELD, ILLINOIS

Circle 342 on Page 19



vided by a self-energized spring. It carries a high current load of 10 amp for precision, low-resistance applications. Operating point of the switch remains constant, assuring high repeatability. High contact force makes the switch safe from contact bounce, contact chatter, shock, vibration, and dead break. Temperature range is −100 to +250 F. **U. S. Switch Corp.**, 7 Jefry Lane, Hicksville, N. Y.

Circle 577 on Page 19

Conveyor Belt

eliminates ply separation

Nylock No. 170 conveyor-belt construction that eliminates ply separation is available in a lightweight design for general industrial use. Body is a solid woven unit, thoroughly impregnated with rubber and encased with rubber covers. There are no fabric plies to separate. Heavy cables of long-staple cotton are interwoven with high-strength nylon into a single, interlocked unit. Cotton cables provide strength, and strands of elastic nylon, running in both directions, provide additional strength, shock resistance, and fastener-holding ability. Belt carcass cannot seperate under impact or by accident. Fastener strength is equal to four plies of 32S fabric. Belt has a tension rating of 170 lb per inch of width. **B. F. Goodrich Industrial Products Co.**, B. F. Goodrich Co., Akron, Ohio.

Circle 578 on Page 19

Rotary Actuator

for use with valves, dampers, other flow-control devices

Combustion Control drive is a two-stage, worm-gear, speed-reduction drive available for use with valves,

dampers, and similar industrial flow-control devices. It permits positive control of spline alignment and engagement when shifting from motor to manual control. Shifting operation is achieved by placing alternate splines along the engaging shaft for turning the output shaft by either the large handwheel or the motor. Large handwheel is stationary; only the shaft moves. In the fractional-hp line, gear motor output torques range from 125 lb-ft at 2.0 rpm and 500 lb-ft at 0.25 rpm for the ⅛-hp model to 1750 lb-ft at 0.50 rpm in the ¾-hp size. Torques in the integral-hp line range from 1000 lb-ft at 2.0 rpm with 1 hp to 1750 lb-ft at 1.5 rpm in the 1½-hp version. Unit can be furnished in standard foot, ring, or shaft-mounted assemblies.

Drive affords a maximum 270 deg angular rotation of the output shaft. **Electra Motors Inc.**, 1110 N. Lemon St., Anaheim, Calif.

Circle 579 on Page 19

FM Transistors

in standard TO-7 cases

Five PADT germanium alloy-mesa RF transistors for FM and AM home and portable radios are low in price. Three of the group comprise a high-frequency FM kit: The 2N2089, 2N2090, and 2N2091 are respectively an RF amplifier, an oscillator-mixer, and an IF amplifier. The fourth, the 2N2092, is universal type for use in standard broadcast and short wave bands up to 6 mc in all stages from RF through IF. The fifth, the 2N2093, is identical to the 2N2092 except for a higher 2-v emitter breakdown voltage figure for use in auto radios. All five types are held to tight specs and feature low collector leakage current, high current gain, and high collector-base breakdown voltage

ROPER PUMPS

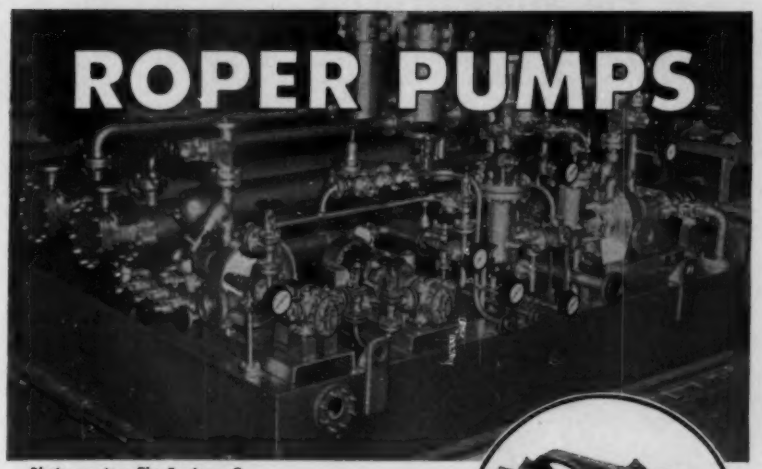


Photo courtesy The Engineer Co.

maintain lubrication of seals and oil bearings on large centrifugal compressor

• CAPACITY RANGE: 5-75 GPM • OPERATING PRESSURES: TO 1000 PSI

The complex lube system for this centrifugal compressor was designed by The Engineer Co. for the Elliott Co. and Blaw-Knox for Ashland Oil Co., using two types of Roper pumps as booster and main lube units. The Fig. 1H15 booster pumps handle 70 SSU viscosity SAE-10 lube oil at operating temperatures of 140°F, and deliver up to 17 gpm at 475 psi pressure. The two main lube pumps are specially modified Roper Series K units handling 76 gpm at 50 psi. Close cooperation with The Engineer Co. by Roper determined the pumps which would best serve the needs of this lubricating system. Special problems involving pump components for your equipment will receive this same skilled assistance by Roper engineers.

RELIABLE SERVICE AT HIGH PRESSURE

- **SPUR GEARS,** specially designed for high volume efficiency at high pressures, are hardened, ground, shaved, and perfectly balanced to operate quietly, smoothly.
- **DRIVE SHAFT,** separate from the drive gear, protects pumping gears from thrust load stress, preserving the axial hydraulic and mechanical balance of the gears.
- **ROLLER BEARINGS** and bronze wearplates are built for heavy-duty use, absorbing stress of heavy loads and continuous service. These parts are lubricated and cooled by liquid being pumped, and are easily, quickly replaced.

Contact your nearest Roper Dealer for specific pump information

Send for our new Series H catalog

ROPER HYDRAULICS, INC.

Dependable pumps since 1857
COMMERCE, GEORGIA

Circle 343 on Page 19

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with McCord Model 55 Lubricator

SAFE-LEVEL SIGHT FEED

That's right! The finest lubricator on the market today has been refined to give you even *more* for your money. Now, the McCord Model 55 Lubricator comes equipped with new, exclusive Safe-Level Sight Feed with these outstanding benefits for you . . . safe, sure warning of malfunction . . . quicker priming . . . better feed regulation . . . extreme accuracy . . . improved reliability. IMPORTANT: Safe-Level Sight Feed can also be added to existing Model 55 Lubricators.

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Circle 344 on Page 19

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YOUR ASSURANCE OF—
✓ *Dimensional Stability*
✓ *Lower Winding Costs*
✓ *Close Tolerances*
✓ *Rigid Flanges*

You SAVE on bobbin costs. You SAVE on tooling costs. You SAVE on winding costs by eliminating costly secondary operations. You SAVE by incorporating economical terminal designs into the molded part. You SAVE by eliminating winding rejects. It will pay you to investigate COSMO NYLON BOBBINS.

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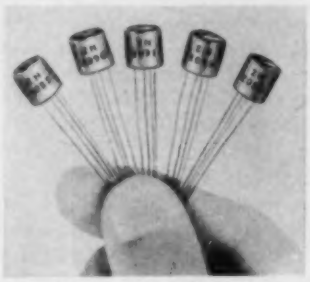
Circle 345 on Page 19



(min of 20 v). Units maintain performance at supply voltages as low as 3 v. All five types are mounted in hermetically sealed, standard TO-7 cases which are internally shielded. **Semiconductor & Special Purpose Tube Div., Amperex Electronic Corp.**, 230 Duffy Ave., Hicksville, L. I., N. Y.

Circle 580 on Page 19

Servo Motor

has output of 0.013 hp at 7500 rpm

Model 2711/20-1 servo motor is composed of a two-phase, 400-cycle, ac motor and a tachometer generator. It has an input rating of 115 v, 0.53 amp; output is 0.013 hp at 7500 rpm. Continuous-duty unit has double mounting brackets to provide easy mounting and added strength for extreme vibration conditions. It meets exacting military specifications, as well as commercial requirements. **Eicor Div., Indiana General Corp.**, 517 W. Walnut St., Oglesby, Ill.

Circle 581 on Page 19

Glass-Fiber Tubing

has low dimensional change under high humidity

Filamite Grade G-12-3730 spirally wound glass-fiber tubing has nearly 2.5 times the burst strength of G-10 tubing. It is bonded with an epoxy resin, and has extremely low water absorption and low dimensional

Circle 346 on Page 19→

A NEW CONCEPT
IN CONTROL CIRCUIT RELAYS

GOLD BONDED CONTACTS

ARROW-HART
GOLD BONDED **RELAYS**

MORE CONTROL CIRCUITS IN LESS SPACE . . . to handle complex control circuits, keeping size of machine or control cabinet to a minimum.

LONGER LIFE and GREATER DEPENDABILITY . . . with superior electrical and mechanical performance, plus the ability to withstand severe vibration and adverse operating conditions.

INCREASED CONTROL VERSATILITY . . . handles a wide range of control requirements with a minimum number of relays.

turn page for technical information

RATED 10 AMPS at 300 VAC

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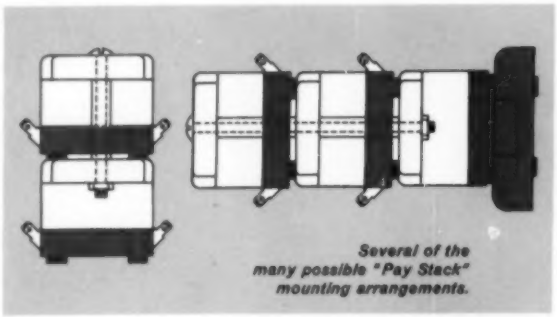
ARROW-HART **GOLD BONDED** RELAYS

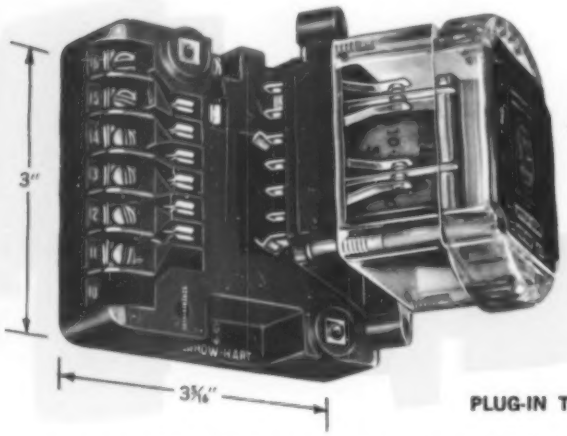
New Design and Construction Features

"PAY STACK" MOUNTING

Gold Bonded Relays operate reliably in any position, and two or more units can be stacked one on top of the other (bottom-to-top *or* top-to-top) as required. Providing the maximum number of control units in a minimum envelope, this Gold Bonded stacking feature pays BIG dividends in space savings!



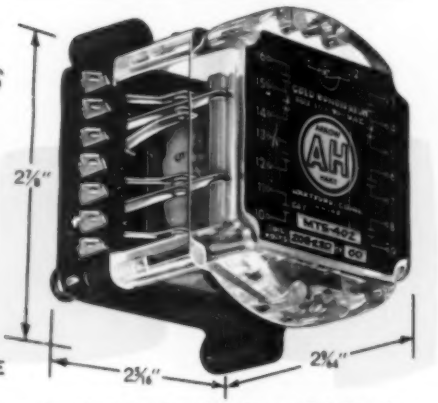
Several of the many possible "Pay Stack" mounting arrangements.



PLUG-IN TYPE

TWO BASIC UNITS

MEET MOST INSTALLATION REQUIREMENTS



SURFACE-MOUNTED TYPE

. . . is designed for use with the sturdy, industrial-type receptacle shown here, but can also be used by itself as a back-wired unit for thru-panel mounting. *Flat, stab-type connections assure positive contacting between relay and receptacle — NO pin-type connections.*

SIMPLE, RUGGED MECHANICAL CONSTRUCTION Gold Bonded Relays are simple in mechanical configuration with a minimum of parts and joints. A complete absence of severe formed parts and soldered movable connections eliminates common sources of mechanical failure. *Smaller, lighter magnets plus short operating movement mean less mass in motion, consequently less pounding.*

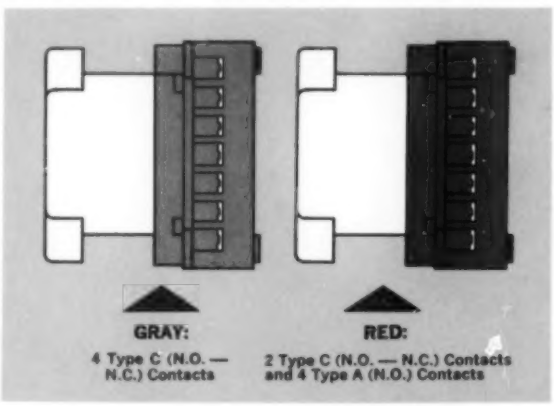
OUTSTANDING ELECTRICAL DEPENDABILITY High-efficiency coils are vacuum impregnated for maximum moisture resistance. Bases are molded from electrical grade melamine, which has low moisture absorption. Cover of clear, molded plastic protects against contamination . . . yet allows instant visual inspection of contacts.

LONG-LIFE "GOLD BONDED" CONTACTS Special Gold Bonded contact tips are silver alloy, impregnated with pure gold. These contacts are not just gold plated. The gold wears in with continued use. This prevents sulphidation of the tips during shelf life, eliminating a major cause of operational failure. Unique cantilever construction means that contacts *must* wipe during operation. Short travel minimizes impact and fatigue.

TWO STANDARD CONTACT ARRANGEMENTS HANDLE PRACTICALLY ALL CONTROL REQUIREMENTS Gold Bonded Relays can be supplied with almost any combination of TYPE A (N.O.), TYPE B (N.C.), and TYPE C (N.O.-N.C.) Contacts. However, the two standard arrangements shown here are capable of handling a vast majority of all control requirements.

. . . is electrically identical to the plug-in model, but is front wired and equipped with quick-connect terminals. Rubber snubbers on base insure firm mounting and reduce transmission of machine vibration to the relay.

COLOR CODED FOR EASY IDENTIFICATION



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Quality since 1890

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WIRING DEVICES • APPLIANCE SWITCHES

FOR ADDITIONAL INFORMATION

. . . on new Gold Bonded Relays, send today for your free copy of Arrow-Hart Circular No. G-2337-535. Includes complete performance test reports, specifications, and ordering data. Write to Dept. MD, The Arrow-Hart & Hegeman Electric Company, 103 Hawthorn Street, Hartford 6, Connecticut.

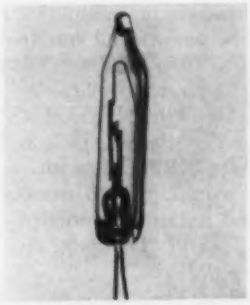
Printed in U. S. A.

change under high humidity conditions. Tubing is recommended for applications which require high burst strength. Available in natural (gray-green) color, tubing has smooth, ground finish or clear-dipped epoxy finish. Plain tubes are 45 in. long and combination tubes are 36 in. long. Standard size range is ID, ½ in. min; OD, 5 in. max, with 3/64-in. minimum wall thickness. **National Vulcanized Fibre Co.**, 1061 Beech St., Wilmington, Del.

Circle 582 on Page 19

Circuit Breaker

is temperature-sensitive, miniature unit



Thermo-Break glass-encapsulated, temperature-sensitive circuit breaker is available for the protection of shaded-pole and permanent split-winding types of electrical motors. Breaker is hermetically sealed and gas filled to allow fast heat transfer between motor winding and breaker. It is 1.26 in. long and has 0.3000-in. diam. Circuit breaker is available in temperature ratings from 50 to 300 C. **Sylvania Electric Products Inc., subsidiary of General Telephone & Electronics Corp.**, 730 Third Ave., New York 17, N. Y.

Circle 583 on Page 19

Remote Position Indicator

consists of sensor and remote indicator

Remote indication of position for butterfly valves, dampers, and other process-control equipment is provided by new sensor and remote meter-type indicator. PF-11 sensor has weatherproof or explosionproof enclosure; face or flange mounting with either straight or hollow shaft

LONGER-SERVICE
HOSE ASSEMBLIES FOR
EVERY REQUIREMENT
STRATOFLEX
HOSE & FITTINGS
OIL & FUEL ASSEMBLIES ON A DIESEL ENGINE
HYDRAULIC ASSEMBLIES ON A MINING MACHINE
AIR BRAKE ASSEMBLY, ON A TRAIN
FREON ASSEMBLIES ON AN AUTO AIR CONDITIONER

VIBRATION PROOF • LEAK PROOF • ABRASION RESISTANT

Manufacturers and users of equipment requiring hose assemblies can depend on Stratoflex flexible hose and hose fittings to reduce downtime through availability, thereby holding maintenance costs to a minimum. Designed for diesel, automotive, general industrial and commercial applications, Stratoflex hose and fittings have the proven durability that is necessary for dependable service. Stratoflex hose and fittings are available in a wide variety of sizes and types to meet every requirement. Shown above are typical installations where Stratoflex hose and fittings are giving economical, dependable service.

For complete information, write for S-2 bulletin. SF1-1

STRATOFLEX Inc.

P.O. Box 10398 • Fort Worth, Texas
Branch Plants: Hawthorne, Calif., Fort Wayne, Ind.
In Canada: Stratoflex of Canada, Inc.
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San Francisco, Seattle
Toronto, Tulsa

←*Circle 346 on Page 19*

Circle 347 on Page 19

- Large Manufactured Head
- Oversize Blind Head
- Plugged or Hollow
- No Stem Trimming
- Minimum Blind-Side Clearance
- Excellent Head Seating
- Wide Grip Range
- Full Range of Diameters
- Positive Hole Fill
- Easy Installation

For fast, secure, more economical fastening, the new Cherry Commercial Rivet is a blind fastener ideal for production manufacturing and repair. Installed by one man from one side of the work, the Cherry Commercial Rivet reduces cost of assembly, repair and maintenance in both blind and open applications.

Minimum blind side clearance, adaptability to variations in material thickness, and positive hole fill even in oversize or out-of-round holes offer advantages not available in other production fasteners.

Cherry Commercial Rivets are available in both hollow (non-structural) and plugged (structural) types. The plugged rivets have strength values comparable to solid rivets, and stems fracture to eliminate all trimming operations and provide further production economy.

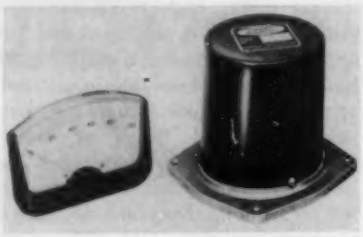
Grip lengths from 1/16" to 1" inclusive, and diameters of 1/8", 5/32", 3/16" and 1/4" are provided in either universal or countersunk head. Special rivets are manufactured to order.

For full technical information on the new Cherry Commercial Rivet, write Cherry Rivet Division, Townsend Company, Box 2157-E, Santa Ana, California.

Aluminum Mild Steel Monel

CHERRY RIVET DIVISION
SANTA ANA, CALIFORNIA
Townsend Company

In Canada: Parmenter & Bulloch Manufacturing Company, Limited, Gananoque, Ontario



for direct coupling. Sensor is available with one or two potentiometers and/or limit switches to provide control functions as well as position indication. Standard models are designed for 90 or 180 deg input rotation; special designs allow 50 or more input revolutions. MR-61 remote position-indicating meter has integral meter circuit board; trimming rheostat for calibration of meter with sensor; and terminal strip for 110-v line and sensor connections. Meter is available for panel mounting or in NEMA 1 or explosionproof enclosure. Unit combines pushbutton control with applications requiring both remote control and indication. **Jordan Controls Inc.**, 3225 W. Hampton Ave., Milwaukee 9, Wis.

Circle 584 on Page 19

Switch Lights

fail-safe units use T-1 3/4 lamps

New Fail-Safe solenoid switch lights operate in the same manner as regular push-on, push-off types, except that in the on position an internal solenoid coil is actuated. If current to this coil is interrupted, switch is disengaged and remains disengaged even though current is resumed. Switching and solenoid mechanism are fully enclosed in a gold anodized case. Complete envelope is 2 5/8 in. long. Case diameter is 3/4 in., and mounting hole is 9/16 in. Circuits to 4PST and 2PDT in various combinations of normally

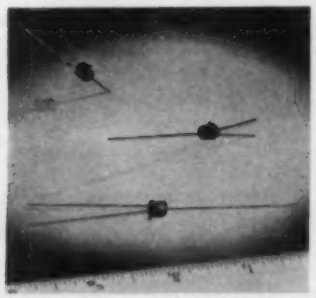
open and normally closed contacts are available. Switch is rated at 28 v dc, 125 v ac to 2 amp resistive. Coils are available in 6, 12, and 28 v. Lamp circuit is independent, employs T-1 ¾ lamps. Plastic pushbuttons can be removed for rebulbing from the front of the panel. **Pendar Inc.**, 14744 Arminta St., Van Nuys, Calif.

Circle 585 on Page 19

Silicon-Controlled Rectifiers

are subminiature units

New silicon-controlled rectifiers are subminiature units with high sensitivity, cutoff characteristics, and inherent reliability. Available in both conventional outline and new in-



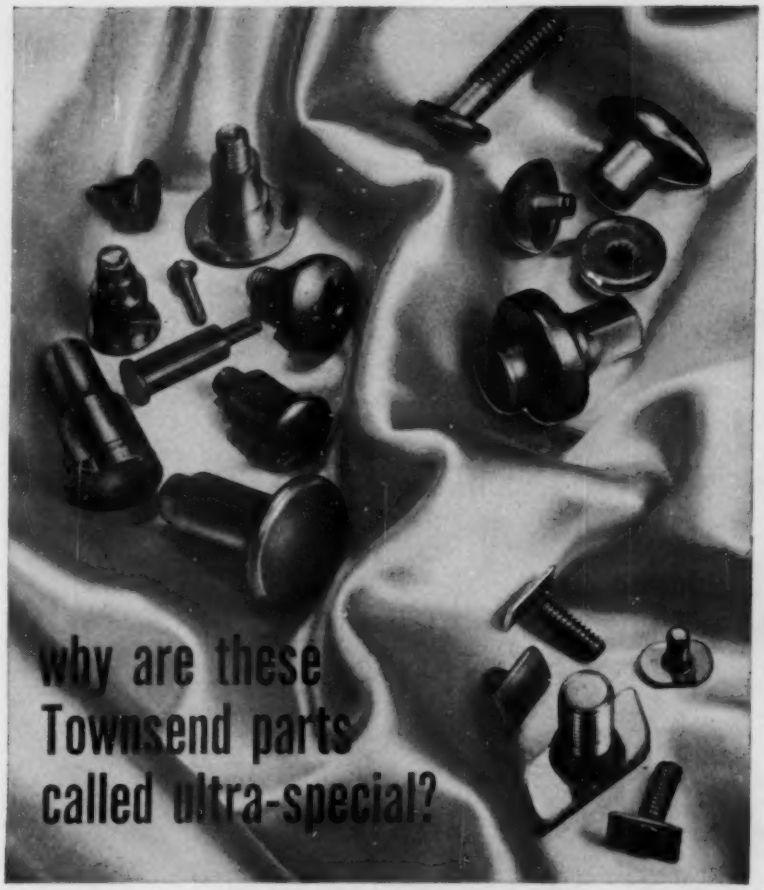
line configuration for welded modules and printed circuits are 2 ma triggering, dc ratings to 200 v and 350 ma, with pulse capability to 10 amp. **Solid State Products Inc.**, One Pingree St., Salem, Mass.

Circle 588 on Page 19

Glass-Epoxy Laminate

meets all military and NEMA specifications

Fireban 1011 glass-epoxy laminated plastic, in a single material, meets all military and NEMA specifications for the various grades of glass-epoxy laminates, and is flame retardant and easily punched. Available in sheet form and as copper-clad laminate for making printed circuits, it combines flame retardance with high mechanical strength and ease of fabrication of Grade G-10 and retention of strength at elevated temperatures specified for Grade G-11. Laminate has a lengthwise flexural strength of 80,000 psi per sq in. for 1/16 in. sheets and



We call the metal parts shown here Ultra-Special because they are the result of completely new cold-forming and finishing techniques. They are typical examples of how users are reducing costs by taking advantage of the strength, improved quality, close dimensions and economy of mass-producing parts by cold-forming.

In the past, the limitations of the cold-forming process forced manufacturers to accept parts which were made by other, more costly methods. Now, through extensive research and development work Townsend is cold-forming Ultra-Special items with intricate shapes and critical dimensions held to tolerances as close as .001 inch. They may be made by combining cold-heading processes with impact extrusions, special heat-treatment and coatings, to name but one of the new techniques.

The use of Townsend Ultra-Special items in your product assembly could provide the means to make better products at lower costs. Investigate by asking a Townsend field engineer to call. Write Townsend Company, Engineered Fasteners Division, P. O. Box 71-E, Ellwood City, Pa.

Engineered Fasteners Division

Ellwood City, Pa.

Townsend Company

ESTABLISHED 1816 • BEAVER FALLS, PA. • A textron COMPANY

In Canada: Parmenter & Bulloch Manufacturing Company, Limited, Gananoque, Ontario

Circle 349 on Page 19

Just Published! *comprehensive book to help you in the selection of gears*

Farrel's new "Gear Manual" is ready for distribution now. Here are 68 pages of practical, authoritative information that you will find helpful when selecting gears.

Sections devoted to gear selection include: nomenclature, formulas for determining dimensions, procedure for calculating horsepower ratings and sample calculations. Gears for special use, such as in rolling mills and kilns and for pump rotors, are covered. Also discussed: lubrication, gear-tooth wear and failure and use of the gear-tooth comparator.

The manual is informative yet easy to use. Where possible, formulas have been simplified to reduce the calculations required.

Write for a copy today on your company letterhead.

FB-1227

FARREL-BIRMINGHAM COMPANY, INC.
P.O. Box 2071, Buffalo 5, N. Y.
Plants: Ansonia and Derby, Conn., Buffalo and Rochester, N. Y.
Sales Offices: Ansonia, Buffalo, Akron, Chicago, Minneapolis, Denver, Los Angeles, San Francisco, Seattle, Salt Lake City, Tulsa, Houston, Atlanta
European Office: Piazza della Republica 32, Milano, Italy

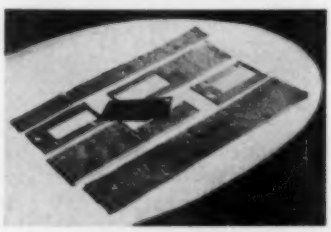
76,000 psi for ⅛-in. sheets. Crosswise flexural strength is 70,000 and 65,000 psi respectively. It retains over 50 per cent of its strength at 300 F. Material has low moisture absorption, excellent chemical resistance, and excellent electrical properties. It is furnished in sheets approximately 37 x 49 in., from 0.010 to 2 in. thick. Copper-clad laminate, Fireban 1011 E, is furnished with electrolytically deposited copper foil having minimum purity of 99.5 per cent. **Taylor Fibre Co.**, Norristown, Pa.

Circle 587 on Page 19

RFI Gasket

for use between complex mating surfaces

Teckmat resilient Monel knitted-wire RFI gasket is a mat structure for use in applications where complexity of mating surfaces is a problem. Shielding effectiveness is rated at 80 to 110 db. Compression-formed to



customer specification, it is generally produced in sizes of under 40 sq in., but large assembly can be made by combining several gaskets. **Technical Wire Products Inc.**, 129 Dermody St., Cranford, N. J.

Circle 586 on Page 19

Latch Relays

mount in place of two center unit poles

Type HRLR ac latch relays are available for machine-tool and other control uses where control circuits must function independently of circuit or power failure. Latch assembly mounts in place of two center unit poles. Mechanically held relays have continuous-duty coils on both main relay and latch assembly; unitized convertible poles; high electrical reliability; and long

(*Please turn to Page 256*)

richard latham: "second generation" designer

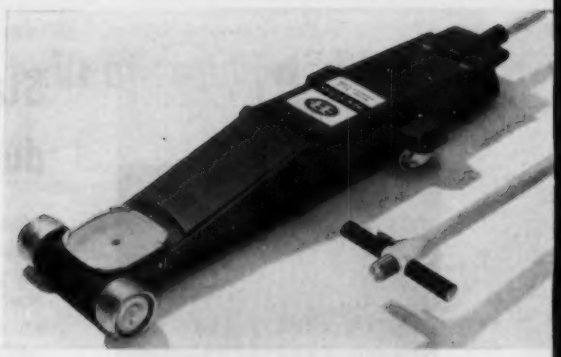
latham talks design

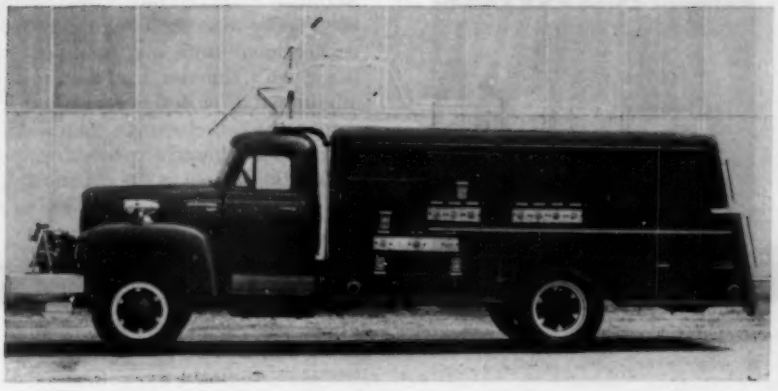
When you think of industrial design, you tend to recall the giants that gave birth to the profession in the late Twenties: Loewy, Teague, and Dreyfuss. But hot on their heels is another generation of designers. One of them is this year's Chairman of the Board of the American Society of Industrial Designers, Richard Latham, a man who as late as 1940 was a combination floor sweeper and designer at Montgomery Ward when it was one of only three Midwestern companies that had design departments.

Those were the days when industry was just beginning to realize that good design represented a competitive advantage. They were the days of Montgomery Ward's "Good–Better–Best" policy in which they used design subtleties to distinguish between three different grades of the same item. "In those days," Latham says, "design was largely a matter of face lifting. Today, industrial design is becoming a true planning function for industry, and the designer is concerned as much with making a product work better as he is with appearance."

Latham is well-qualified to tackle any problem of form or function. During World War II he worked in engineering research and development on aircraft, including the jet fighter, weapons systems and ballistics, and the first air-borne radar system. After the war he devoted five years abroad to the German porcelain industry. Since then his work has centered on "hard" products and transportation. Included in the latter are work on the new Greyhound Bus and the DC-6 and DC-7 aircraft series. Since early 1955, he has headed his own industrial design firm of *Latham, Tyler, Jensen* and worked on ceramic consumer products, corporate identity programs, the design and marketing of housewares, retail shop layouts, aircraft instrumentation and design of medical equipment. A number of striking exhibits have been designed by *Latham, Tyler, Jensen,* including the Cantigny War Memorial Museum at Wheaton, Illinois, and they're currently working on the Hall of Health for the California Museum of Science and Industry.

What is the designer's function today? "The real question," Latham says, "is what *should* it be? Industry is using industrial designers to create or redesign products for next year's markets, or at the most just a few years ahead. But the industrial designer's real talent lies in genuine innovation, in crystallizing the reality of not only what a product might be, but what it *can* be. He conceives of totally new products that aren't even





in existence today, and then gets down to the hard work of adapting them to the home, to the everyday business of living. The true industrial designer works years ahead. He dreams. Short-term design and redesign on the other hand, should be a staff function of industrial corporations where it can be integrated into the total marketing plan, including product development, sales, market development, merchandising. Then the true industrial designer can act as a pure consultant to industrial management." Is he needed? "Woefully. He's the only artist in business."

"But let's not confuse the artistic designer with the Left Bank," Latham says. "Industrial designers are—and have to be—hard-headed businessmen who must know what will sell and how well and easily the product can be manufactured. I haunt machine shops and production lines," Latham says. "I talk to workers and foremen and try to analyze production problems, as well as educate them about what we're striving for in the product design. Just as unrealistic design can make the production man lose his hair, a lack of understanding on the part of production people and insistence on long-standing production techniques can often ruin a design."

Selection of the right material for a design is another Latham trademark. The material must be capable of convenient fabrication, it must express the personality of the product that the designer is trying to achieve, and it must help move the product off shelves and showroom floors.

Latham has used dozens of different materials, and it is no coincidence that the majority of his firm's product designs have used steel in one way or another. He says, "Steel, after all, was the first metal available to man that could be stretched and pulled into form. Steel, to the designer, is form in tension. It has an inner strength that you feel. It was the first material that had enough ductility to be formed and drawn, yet at the same time enough strength to make a skeleton from which things could be hung, such as auto frames and certain types of architectural systems. And let's not overlook the fact," Latham says, "that this modern metal is the same one that made mass production possible."

The moral? Steel in its many forms has been with us for years, yet it continues to excite the imagination of people like Dick Latham and his associates who make a business of designing for the future.

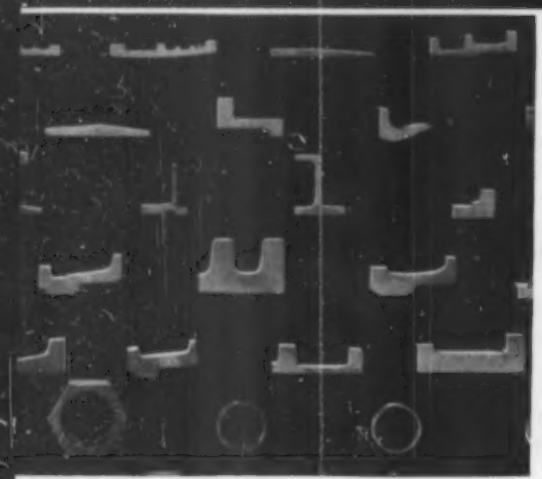
USS United States Steel
TRADEMARK

Please direct inquiries to advertiser, mentioning MACHINE DESIGN

Stainless Steel heat exchangers duplicate outer space at −443°F

Missile scientists have turned to Stainless Steel to duplicate atmospheric conditions in outer space and save the great expense of actually firing missiles for pure test purposes. They can create temperatures as low as −443°F in Stainless Steel heat exchangers—and reduce air pressure to one-billionth of an atmosphere. Here is the problem Stainless solved: high-velocity-gas research demanded a heat exchanger that combined rapid cooling, compactness, lightness and freedom from contamination. For Tranter Manufacturing Company, fabricators of the unusual heat exchanger shown in the picture, Stainless filled the bill. Their Stainless "Platecoil" heat transfer unit cools 50% faster than conventional coiled pipe designs; it weighs half as much as conventional units, and occupies only one-half the space. Because of Stainless Steel's superior corrosion resistance, problems of corrosive scaling are eliminated. Pipe design is unusual. Two sheets of Stainless are embossed with serpentine half-channels, then welded together. Stainless "Platecoil" is used to jacket the launching tubes on the Polaris submarine, and has many more conventional uses in the chemical, food processing and petroleum industries. No other metal could do the job as well as Stainless Steel.

USS Design Steels:



Cut costs with USS Special Sections

A USS hot-rolled special section is an irregular steel shape, designed specifically for one purpose and rolled so that there is little or no finishing required to meet final specifications. It is difficult to predict *where* a special section can come into a design. Its adoption follows a detailed analysis of production operations, such as machining, grinding, welding or riveting; a study of scrap losses, freight economies, and a close look at mechanical requirements. Take a close look at some of the parts now being used in your designs. If you come to a conclusion that money can be saved or reliability can be improved, get in touch with us. If you want to see how manufacturers have made good use of USS Special Sections, write for our booklet, "Hot-Rolled Carbon Steel Special Sections."

This mark tells you a product is made of modern, dependable Steel.

600,000-barrel capacity storage tank built of USS "T-1" Steel

The world's largest oil storage tank is located in Mena Abdulla, Kuwait, on the Arabian Gulf. It was built by the Chicago Bridge & Iron Company of high-yield-strength USS "T-1" Constructional Alloy Steel. Its contents can fill a new super-tanker in one stop instead of several. By using "T-1" Steel, the contractor was able to save fabricating, shipping and erecting costs and get *extra* strength and corrosion resistance.

The tank is 64 feet high and 260 feet in diameter. The shell consists of six 8-foot rings of "T-1" Steel, made to 115,000 psi minimum ultimate strength, and two top 8-foot rings made of A 131 grade A carbon steel. The tank has a Horton pontoon floating roof and the bottom of the vessel was made of A 283 grade C plates ¼-inch thick. The "T-1" Steel shell thicknesses, which ranged from one inch down to ½-inch, were determined on the basis of a design stress of 38,333 psi, ⅓ of the minimum ultimate strength of the steel. Joint efficiency: 100%. By using USS "T-1" Steel in the lower rings, *42% less steel* was required.

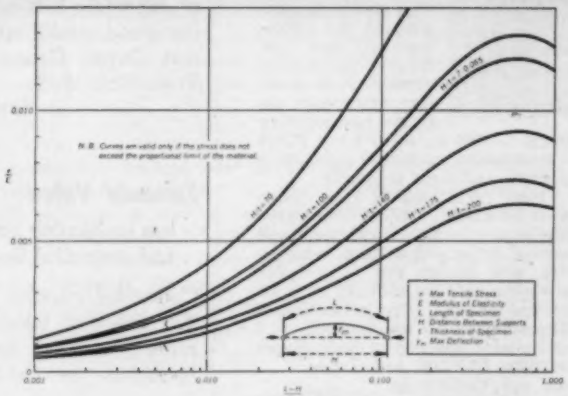
USS "T-1" Steel offers the designer exceptional strength and toughness, even at very low temperatures. Some suggested uses are pressure vessels, equipment-hauling trailers, LP gas transports, offshore rigs and other equipment that must be strong, light and corrosion-resistant. Our booklet, "USS 'T-1' Steel," tells the whole story. Write United States Steel, 525 William Penn Place, Pittsburgh 30, Pa.

"HORTON" is a registered trademark of Chicago Bridge & Iron Company

new solutions for new problems

U.S. Steel offers information on stress corrosion

U. S. Steel researchers have been carrying on a program to determine the suitability of several very high strength alloy and stainless steels for aircraft and missile applications. Pictured here are several steel bands that have been tested to failure as part of this program. The study includes the effects of heat treatment and coatings on stress corrosion, and discusses the microstructural characteristics of stress corrosion cracks. The study is called, "Stress Corrosion of Steels for Aircraft and Missiles." Get your copy by writing to United States Steel. USS and "T-1" are registered trademarks of United States Steel.



For the literature offered here, or for additional information, write to United States Steel, Room 6357, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

USS United States Steel

Please direct inquiries to advertiser, mentioning MACHINE DESIGN

(Continued from Page 254)

operating life. Available with two, three, four, or six normally open or normally closed unit poles, relays are obtainable with standard coils to 220 v, 60 cycles, ac. **Ward Leonard Electric Co.**, Mount Vernon, N. Y.

Circle 589 on Page 19

Silicone Paste

for use in temperatures from −75 to over +400 F

White, all-purpose, silicone-rubber paste, designated RTV-77, is for high and low-temperature industrial sealing, patching, and caulking applications. Material cures at room temperature to a solid-rubber material that can be bonded easily to many metal and other surfaces. RTV-77 is useful in a temperature range from less than −75 to above +400 F. Material is thixotropic in uncured form, which prevents flow or sag while it is being applied under static conditions. **Silicone Products Dept., General Electric Co.**, Waterford, N. Y.

Circle 590 on Page 19

Solenoid Valve

has cushioning action and controlled flow

Controlled cushion action of Type 205 two-way solenoid valve minimizes line shock induced by valve operation in hydraulic circuits.

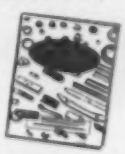
RULON'S "Plastic Memory" Means Tighter Seals . . . Lower Costs

RULON (reinforced TFE) parts post-formed from tape are ideal for seals, packings, rings, etc. because they exhibit no stick-slip and greatly reduce starting torque. And unlike rubber or leather, RULON takes any hydraulic fluid – and its plastic memory insures positive contact with shafts or cylinder walls. Parts have infinite shelf life, too – completely unaffected by weather, light or heat.

Dixon's RULON and TEFLON in
- rods
- tubing
- sleeving
- sheet
- tape
- extruded shapes
- bearings
- bushings
- washers
- gaskets and packings
- bearing retainers
- machined and molded parts

Dixon's self-lubricating RULON gives your sealing applications all the advantages of Teflon – low friction, chemical inertness, zero moisture absorption, extreme temperature range (−400 to +500°F) – PLUS a tremendous increase in mechanical strength and wear resistance.

Next time, look at your design with RULON in mind. This material is now available with improved sealing action and at costs competitive with leather and rubber. For complete data on stamped or post-formed parts . . . special reinforced fluorocarbons for special needs . . . and a wide selection of basic shapes in both RULON and Teflon . . . see our Catalog in Sweet's Product Design File, or write for Brochure #9572. DIXON CORPORATION, 100 BURNSIDE ST., BRISTOL, R. I.



* DuPont T.M.

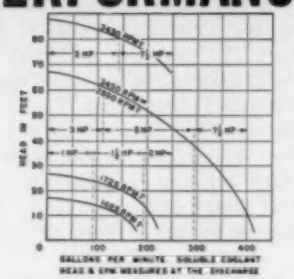
DIXON

Circle 352 on Page 19

Gusher

Coolant Pumps are

PROVED IN PERFORMANCE



Performance chart is for Model 11025

You can be sure that your GUSHER Coolant Pumps will give you year after year of highly satisfactory service. GUSHER Pumps are built to last the life of the machine they service.

Model 11025 is an immersed type Gusher Coolant pump for installations where deep tanks are necessary.

Model 11024 CM Long for pump installations requiring standard NEMA foot mounted motors to meet J.I.C. specifications. Available in ¼ HP and larger.

Gusher, fully portable, Tank Units are available in capacities from 10 to 50 gallons.

Write for Catalog

THE Ruthman MACHINERY CO.

- COOLANT PUMPS
- CIRCULATORS • AGITATORS
- MOLTEN METAL PUMPS

1811 Reading Road
Cincinnati 2, Ohio

Circle 353 on Page 19

Linear flow is maintained throughout gradual opening and closing cycles by a tapered valve disc. Valve prevents line shock from damaging sensitive gages or instruments, and is easily adapted for automatic time-cycle operation of hydraulic cylinders with the addition of a limit switch. When equipped with a metering adjustment, valve flow can be regulated from 0 to 1 gpm at 400 psi through standard 1/16-in. orifice. Opening or closing cycle is ¼ sec. Valve is rated for 400-psi differential pressure; burst pressure is 6000 psi. Standard valve handles hydraulic or pneumatic media at temperatures from −45 to +185 F continuous duty. Valve operates in any position on ac coil voltages of 6 to 440 v, 50 to 60 cps, or 6 to 220 v dc. **Allied Control Co. Inc.**, 2 East End Ave., New York 21, N. Y.

Circle 591 on Page 19

Printed-Circuit Connector

has 210 terminals

New 17-in., double-row connector with 210 terminals provides choice of three types of contacts—pierced, straight dip solder, or right-angle dip solder. Standard insulator material is diallyl phthalate, per MIL-M-18794, that withstands 450 F. Bifurcated contacts are beryllium copper, silver plated and gold flashed. Current rating is 10 amp maximum and voltage breakdown at sea level is 3200 v dc. **Viking Industries Inc.**, 21343 Roscoe Blvd., Canoga Park, Calif.

Circle 592 on Page 19

Precision Thermostat

resists vibration, shock, and salt spray

Subminiature snap-acting thermal switch, No. 3001-2, meets or surpasses all applicable military specifications. It is hermetically sealed and resistant to vibration, shock,

NOW...COMPLETE PROTECTION AGAINST MOTOR BURNOUT

COSTS HALF AS MUCH AS HALF PROTECTION!

Who says so? The manufacture of a line of U/L approved 3-phase ¼ to 3 hp motors (name on request) proves that the installed cost of a KLIXON 3-phase Inherent Motor Protector is less than half that of the most dependable remote protection. Figures are based on comparative costs of three-phase magnetic contractors and two overload relays versus a KLIXON 3-phase Inherent Protector and a manual selector switch.

Complete protection versus half protection. Remote protectors, responsive only to current, guard your motors against overheating and burnout only in cases of stalling, locked rotor, single phasing and extremely heavy overloads. KLIXON Inherent Motor Protectors, responsive to both current and temperature, extend that protection to cover running overloads, plugging, increased ambient temperatures, blocked motor ventilation, line voltage fluctuations and any condition resulting in excessive winding temperature. So, why be half safe when you pay only half as much for full protection?

Why not get complete protection? Specify KLIXON 3-phase Inherent Motor Protectors, and get complete protection for all your single and dual voltage 3-phase motors from ⅛ to 15 hp. For complete data, write for Folder "Mr. Motor User."

METALS & CONTROLS INC.
3212 FOREST ST. • ATTLEBORO, MASS.
A CORPORATE DIVISION OF
TEXAS INSTRUMENTS
INCORPORATED

Circle 354 on Page 19

design with

DANCO

in mind

Have you a problem calling for tough, abrasive-resistant, non-corrosive and long-wearing tubing? Then, design with *Danco* in mind. Whether it's tubing, pipe, rod or strip, you can depend on the uniform quality and performance of *Danco*. These extrusions in Nylon and other engineering thermoplastics answer the challenge of many design problems where you are seeking a new way . . . a better way . . . at lower cost—

design ideas — briefly.

- Economical non-corrosive **DANCO TUBING and PIPE** for carrying air, cold water, blood, gasoline, and food and milk.
- Gears, bushings, bearings, and other machine parts are easily machined to close tolerances from **DANCO ROD and HEAVY WALL TUBING**
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- If you are designing, keep *Danco* in mind. Our experienced trained field engineers can help right from the start.

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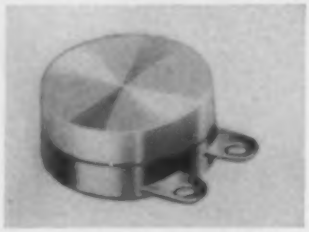


and salt spray. Creeping and false cycling has been eliminated by instantaneous make-and-break action. Insulation between the bimetal disc and electrical contact arm insures control response from ambient temperatures only. **Thermal Inc.**, 669 Elmwood Ave., Providence, R. I.

Circle 593 on Page 19

Air Bearing Spindles

have rotational accuracy of one-millionth of an inch

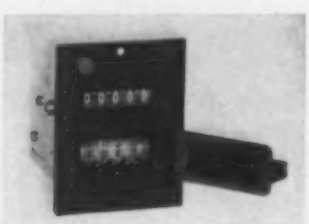
Zeron externally pressurized air bearing spindles have rotational accuracy of one-millionth of an inch. Both radial and axial runouts are held to a millionth. Spindles use "annular capillaries" to control fluid flow through the bearing, eliminating the need for pads and orifices. Spindles have a radial deflection rate of 2½ millionths per lb and an axial rate of ½ millionth per pound when they are operated on filtered shop air at 170 psi. Proportionally greater rigidity is possible with pressures to 2000 psi. Air consumption is approximately 2 cfm at 170 psi. Spindles can be operated in any position. **Professional Instruments Co.**, 6824 W. Lake St., Minneapolis 26, Minn.

Circle 594 on Page 19

Predetermining Counter

has pushbutton reset

Model F 185 predetermining electrical counter is a panel-mounting unit with pushbutton reset. Visual



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Victor Mfg. & Gasket Co., P.O. Box 1333, Chicago 90, Ill.—Canadian Plant: St. Thomas, Ontario.

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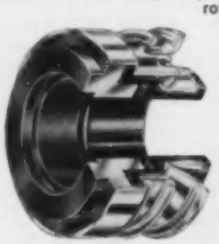
TYPE 6

HIGH-FLEX, low-pressure bellows seal

Working Pressure: 0 to 10 PSI (Dependent on shaft size and projected diaphragm area)
Temperature: +250° F
Speed: 1800 to 3600 RPM

TYPE 8

SELF-CONTAINED, heavy-duty rotating shaft seal



Working Pressure: 0 to 40 PSI Normal 100 PSI Maximum
Temperature: +250° F (Higher with special rubber compounds)
Speed: Up to 3600 RPM (Higher speeds depending on pressure/temperature relation)

VICTOR VICTO-SEAL AXIAL FACE SEALS

A VICTOR QUALITY PRODUCT . . . World's Leading Manufacturer of GASKETS • OIL SEALS • PACKINGS • MECHANICAL SEALS

Circle 356 on Page 19

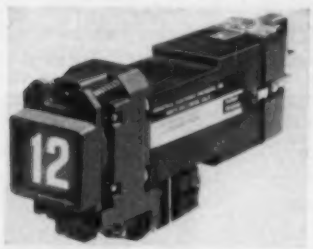
wheels give true progress count. Presetting is by means of a parallel set of wheels underneath the hinged cover. Upon reaching the preset count, an SPDT knockoff switch is thrown. Switch is reset to normal only with the pushbutton. Count rate is 25 per sec, and panel dimensions are 2½ x 3⅜ in. **Presin Co. Inc.**, 2014 Broadway, Santa Monica, Calif.

Circle 595 on Page 19

Indicator Switch

has built-in readout with 12-display capacity

Cue indicator switch replaces up to twelve conventional labeled switches, using about 1/12 the panel space. Visual display on a 1-in. square



pushbutton face is provided for up to 12 different circuits. Colors, numbers, words, letters, or symbols can be used. **Industrial Electronic Engineers Inc.**, 5528 Vineland, North Hollywood, Calif.

Circle 596 on Page 19

Wire-Braid Hose

for pressures to 1000 psi

Super Ortac hose handles air, water, oil, or petroleum solvents at working pressures to 1000 psi. Working pressure provides a five-to-one safety factor from the minimum burst level of 5000 psi. Hose also will handle steam at saturation to 150 psi. It is available in IDs of ¼, ⅜, ¾, and 1 in. with covers in red, black, or yellow for coding of multiple lines. Covers are neoprene for oil and abrasion resistance and good aging characteristics. Hose is furnished in lengths to 100 ft in the two large sizes and in 50-ft lengths in small sizes. **Goodyear Tire & Rubber Co.**, Akron 16, Ohio.

Circle 597 on Page 19

'Jeep' Industrial Engines power leaf collectors.

Exclusive in America

'Jeep' F-HEAD INDUSTRIAL ENGINE

F-HEAD DESIGN! The intake manifold is an integral part of the head providing a preheated fuel mixture. And, the F-Head's large intake valves permit better breathing characteristics than conventional designs. The Total Result: More power in a compact size.

SPECIAL FEATURE! Wherever this engine is in action... dirty streets or dusty building sites... the *positive* crankcase ventilation system *filters* air and *pumps* it into the engine. Corrosive engine condensates are removed. No abrasive dust gets in. Also, Positive Valve Rotators, Stellite or Eatonite Exhaust Valves, Valve Inserts, and more at no extra cost. The Total Result: Extra long-life for your customer... more competitive pricing for you.

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Circle 357 on Page 19

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ENGINEERING DEPARTMENT

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Pressure Transducers

are thin, flexible units with size of 1 x 1 in.

Series 210 Filpip pressure transducers are designed for −10 to 10 psig range. They are linear, have high frequency response, and low hysteresis. Sensors have a thickness of 0.035 in. and over-all size of 1 x 1 in.; sensitive area is 1 cm². They respond only to normal forces, and can be subjected to high vibration and acceleration with little error. Transducers can be applied directly to the plane or curved surface against which pressure is to be measured, or can be suspended in a fluid. They can be built into other structures for acceleration on deflection measurements. They are supplied with 4 ft of 1/16-in. flexible shielded cable. **Spitz Laboratories** ıc., Yorklyn, Del.

Circle 598 on Page 19

Dual-Gun Oscilloscope

has two amplifiers with 100 mv to 100 v sensitivity

Model 5 Mc-2P/R dual-gun compact oscilloscope weighs 22 lb and contains only two types of vacuum tubes. It has two identical vertical amplifiers, each with a band pass of dc to 5 mc and a sensitivity of 100 mv to 100 v continuously adjustable. A built-in preamplifier increases the sensitivity of the lower amplifier to 1 mv per cm. Linearity

of the sweep is 1 per cent from a constant - current, RC network. **Packard Bell Electronics**, P. O. Box 337, Newbury Park, Calif.

Circle 599 on Page 19

Strain Gage

for operation to 180 F

Type S-301 is a 350-ohm, flat-grid, paper-base, wire strain gage with grid dimensions of ⅞ by 5/16 in. Operation is possible to 180 F. Each gage is marked with gage factor, resistance, and lot number. **Metrix Inc.**, P. O. Box 683, Walnut Creek, Calif.

Circle 600 on Page 19

Vibration Analyzer

is fully transistorized

Model 40 vibration analyzer is a precision unit having provision for two separate inputs. Calibrated panel meters indicate frequency and amplitude of signals in the micro-inch range from pickups applied to machinery. Unbalance phase data are provided by a high-intensity stroboscope flashed in synchronism with the resulting frequency of vibration. Selective filter separates the vibration-frequency components over a broad range from 170 to 300,000 cpm. Instrument is fully transistorized and is designed in plug-in modular circuits. Should maximum portability be desired, unit can be

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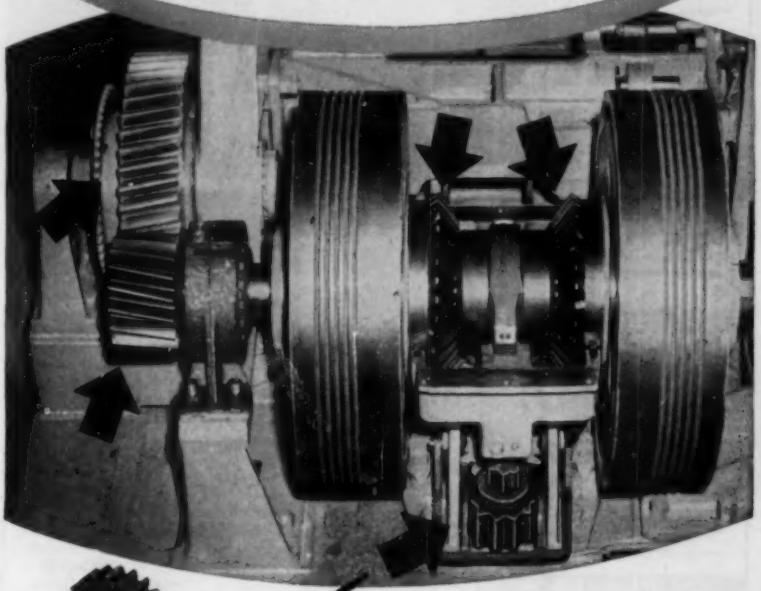

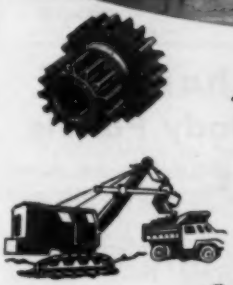

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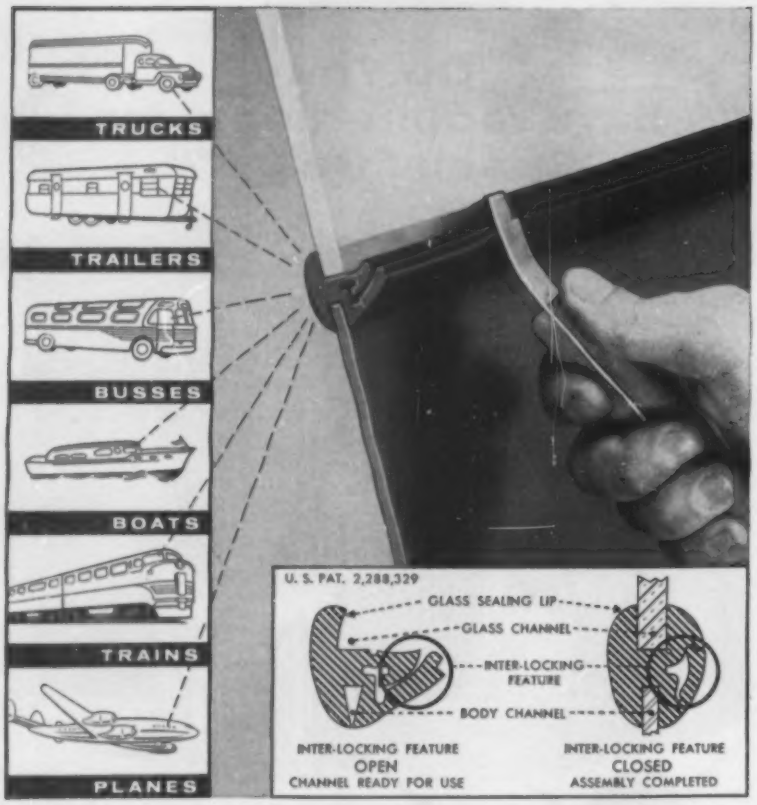
Circle 359 on Page 19



Self-Locking Rubber Channel for Mounting Glass in Body Panels

Its *one-piece* design locks and seals in one operation. No extra locking-strip needed. It's the faster, simpler method for mounting glass in any type body panel—truck, trailer, bus, boat, train, plane, etc.

Extruded with inter-locking feature at direct right angle to body, the Continental Channel permits unhampered insertion of glass. Locking tongue is pressed into its matching groove which forces the lips against *both* the glass and body panel—a more positive seal with exceptional push-out pressure.

Compounded for maximum weather resistance and extra long life. Close durometer tolerances are held for uniformly tight seal against moisture and surest possible locking. These rubber channels can be positioned first on *either* glass or body panel. All details are shown in illustrated brochure gladly sent on request.

Ordered and re-ordered by the most prominent body builders, this Self-Locking Channel is another example of the creative thinking and ingenuity behind rubber parts by Continental. When you need rubber parts to do a specific job, call a rubber specialist *during the planning stage*. This often makes for economy as well as better end results. Call Continental —rubber specialists since 1903.

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In addition to custom-made parts, Continental offers an extensive line of standard grommets, bushings, bumpers, rings and extruded shapes. Hundreds of these are shown in the No. 100 Engineering Catalog. Send for a copy or refer to it in Sweet's Catalog for Product Designers.

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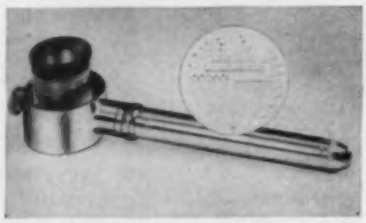
battery operated. Two separate panel-selected inputs provide immediate comparison of vibration signals from two separate pickup points. Individual plug-in input adapters permit the two pickups to be of different types and to have virtually any characteristics. **Raydata Corp.**, 1078 E. Granville Rd., Columbus 24, Ohio.

Circle 601 on Page 19

Pocket Comparator

is enclosed in battery-operated illuminator



Accurate pocket comparator with illuminator is available for checking, measuring, and inspecting small parts. It has a glass etched reticle, and is enclosed in a battery-operated illuminator. Comparator can be used inside machines and in other dark places, and gives measurements in decimal inches and millimeters. Unit has six-power magnification. Protective leather case is included. **Edmund Scientific Co.**, Barrington 70, N. J.

Circle 602 on Page 19

Recycling Timer

maintains time intervals from 0.05 to 5 sec

Model A Regent electronically controlled recycling timer for testing equipment has independent "on" and "off" cycle adjustment which maintains accurate time intervals on either cycle from 0.05 to 5 sec (6 to 600 cpm). Unit is a double-pole, double-throw, 10 amp, 115 v ac switching relay. Starting is instantaneous and requires no warm-up period. Power consumption at peak is less than 3 w. Unit is housed in a standard meter case, 6 13/16 x 5 9/32 x 2 5/32 in. **Hufco Industries**, 2815 W. Olive Ave., Burbank, Calif.

Circle 603 on Page 19

Circle 360 on Page 19

THE ENGINEER'S

Library

Recent Books

Proceedings of the International Conference for Teachers of Mechanisms. *Edited by F. R. Erskine Crossley; 226 pages, 6⅝ by 9¼ in., clothbound; published by The Shoe String Press Inc., 965 Dixwell Ave., Hamden, Conn.; $10.00 per copy.*

Eleven original papers by authors from Germany, Holland, Australia and the United States are presented on applied mechanics, machine design, and mechanical systems synthesis. Specific topics include cam dynamics; dynamic mechanisms and nonlinear control systems; harmonic analysis of the four-bar linkage; and intermittent motions and special mechanisms. Round-table discussions on future teaching of mechanisms and a list of historical books are included.

Handbook of Astronautical Engineering. *Edited by H. H. Koelle; 1890 pages, 6¼ by 9¼ in., clothbound; published by McGraw-Hill Book Co. Inc., 330 West 42nd St., New York 36, N. Y.; available from* MACHINE DESIGN, *$27.50 postpaid.*

Organized in six major parts, this handbook provides a comprehensive summary of technical and engineering data in the space-flight field. The parts are as follows:

1. Fundamentals of Astronautical Engineering—application, materials, fabrication, and program management and planning.

2. Astrodynamics—flight performance calculations, trajectories, basic relationships of aerodynamics, heat transfer, and relativistic flight mechanics.

3. Astrionics—principles of navigation, control, communication and electric systems engineering, components and equipment, and developing integrated systems.

4. Propulsion Systems—laws and means of propulsion, air breathing, solid propellant, and liquid propellant systems, and advanced propulsion systems such as nuclear, electric, solar, and photon.

5. Space Vehicles—orbital carrier vehicles of today and space vehicles

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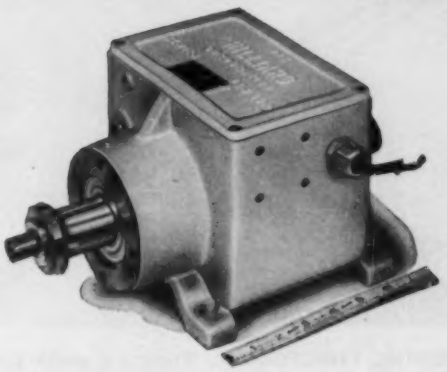

A complete, packaged unit that gives you precise control of intermittent motion from a constant rotary power source!

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- Operating speed from 40 to 400 R.P.M.
- Torque capacity 36 ft. lbs.
- No cumulative error in cycling.
- Instant engagement.
- Mount with direct coupling connection or use with belt, chain or gear drive.

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Write on your letterhead stating your intermittent motion problems and we will provide complete information.

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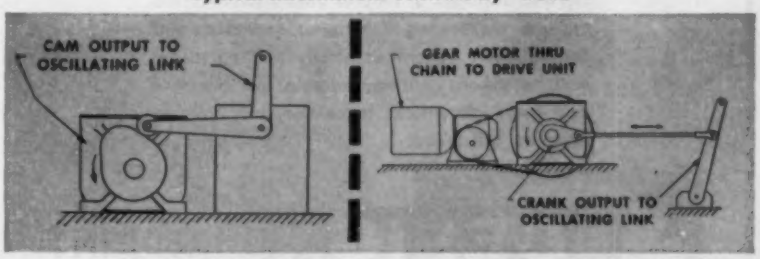

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of the future, principles of design, vehicle design parameters, and body temperatures.

6. Space Flight Operations—fundamentals for instrumented and manned space vehicles, crew engineering, piloting, cockpit instrumentation requirements, and flight evaluation.

Technical Illustration. *By A. D. Pyeatt; 113 pages, 8½ by 11 in., paperbound or clothbound; published by Higgins Ink Co. Inc., 271 Ninth St., Brooklyn 15, N. Y.; $5.00 per copy, paperbound; $6.50 per copy clothbound.*

The basic concepts and techniques of technical illustration are presented in seven parts. The first part, industrial visual aids, defines the technical and industrial illustration function. Succeeding parts cover perspective drawing, axonometric drawing, time-saving devices, correct use of drawing equipment, and rendering techniques. The final part, technical manual illustration, discusses manual production phases, manual view types, data analysis, page layout, and final rendering.

Government Publications

OTS Technical Reports. Copies of reports listed below are available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.

TN D-875. Heat Transfer to an Electrically Conducting Fluid Flowing in a Channel with a Transverse Magnetic Field. By Morris Perlmutter and Robert Siegel, Lewis Research Center, Cleveland, Ohio; 41 pages, 8 by 10½ in., paperbound, stapled; $1.25 per copy.

An analysis is made for forced-convection heat transfer to laminar flow of an incompressible electrically conducting fluid between parallel plates. The plates are heated (or cooled) with a uniform wall heat flux, and internal heating within the fluid is present from viscous and electrical dissipations. Results give the wall temperatures that will be present for various magnetic fields and electric current flows and the duct length required to obtain a fully developed temperature distribution in the fluid.

Effect of Inert, Reducing, and Oxidizing Atmospheres on Friction and Wear of Metals to 1000 F. TN D-1163. By Donald H. Buckley and Robert L. Johnson, Lewis Research Center; 26 pages, 7¾ by 10¼ in., paperbound; $0.75 per copy.

Experiments were conducted in inert, reducing, and oxidizing atmospheres to determine their influence on friction and wear properties of various metals. Nitrogen, argon, "forming" gas, and various concentrations of oxygen in nitrogen were used.

A Linear Theory for Inflatable Plate of Arbitrary Shape. TN D-390. By Harvey G. McComb Jr., Langley Research Center; 55 pages, 7¾ by 10¼ in., paperbound; $1.50 per copy.

A linear small-deflection theory is developed for the elastic behavior of inflatable plates of which "Airmat" is an example. Included in the theory are the effects of a small linear taper in the depth of the plate. Solutions are presented for some simple problems in the lateral deflection and vibration of constant-depth rectangular inflatable plates.

REPRINTS

Complete reprints of major article series and collections of articles, and extra copies of MACHINE DESIGN *Books*, are available from: Reader Service, MACHINE DESIGN, Penton Bldg., Cleveland 13, Ohio. Remittance or company purchase order must be enclosed with your order. Add 3 per cent to orders in Ohio to cover State Sales Tax.

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DC Motor Control, by J. Ronald Wickey, 1961 (42 pp.) $1

AC Motor Control, by J. Ronald Wickey and Arthur S. Newman, Jr., 1960-61 (40 pp.) $1

Preventing Fatigue Failures, by F. B. Stulen, H. H. Cummings, W. C. Schulte, 1961 (32 pp.) $1

Simplified Vibration Analysis by Mobility and Impedance Methods, by R. P. Thorn & A. H. Church, 1959-1960 (80 pp.) $2

Inside the Engineer, by Eugene Raudsepp, 1958-1960 (52 pp.) $1

Mobility of Cross-Country Vehicles, by M. G. Bekker, 1959-1960 (32 pp.) $1

Engineering Approach to Hydraulic Lines, by Jaroslav J. Taborek, 1959 (36 pp.) $1

Planning New Products, by Philip Marvin, 1953-1958 (102 pp.) $3

Friction-Clutch Transmissions, by Z. J. Zania, 1958 (30 pp.) $1

Design Guide—Flexible Couplings, by Leo F. Spector, 1958 (28 pp.) $1

Special Report on Electric Motors, Staff Report, 1958 (42 pp.) $1

Electronic and Electric Power Supplies (Symposium), 1958 (40 pp.) $1

Human-Factors Engineering, by J. D. Vandenburg and C. T. Goldsmith, 1958 (32 pp.) $1

Mechanics of Vehicles, by Jaroslav J. Taborek, 1957 (94 pp.) $2

Design for Fatigue Loading, by Joseph Marin, 1957 (34 pp.) $1

Hydraulic Servo Fundamentals, by J. M. Nightingale.
Volume 1: May-Nov., 1956 (32 pp.) $1
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C. W. Wertz, Application Engineer, Industrial Heating Dept., General Electric Co.

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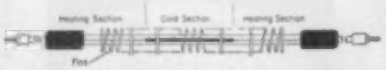
NO SUBSTITUTE FOR EXPERIENCE

The main function of a "component application specialist" is to recommend the lowest-cost component in the correct size, rating, and material to do the job. Experience permits a quick study to be made of the application; previous approaches which have already been tried and proved inadequate can be discarded immediately. Simple suggestions can make significant improvements in the performance of the product, and, many times, the over-all cost can be reduced with no sacrifice in quality.

HERE'S AN EXAMPLE: A manufacturer of egg washers was experiencing heater sheath melting when the equipment ran dry. We investigated and found that copper heaters were used. By substituting stainless steel sheath—at no change in price—this problem was eliminated. The stainless steel will operate dry for relatively long periods with no sheath deterioration, at a temperature that melts copper.

ANOTHER RECENT EXAMPLE: A manufacturer of commercial refrigerated meat and ice cream cases was having trouble with defrost heaters for eight- and twelve-foot units. We investigated the design completely and found that air was blown over the heater and coils by three motors and fans. No air was circulating in the area between the fans. This arrangement required three heaters, with expensive assembly and wiring; or one heater, which caused hot spots and melting of the food between fans. We worked with the design engineer to supply one heater, with cold sections. This not only eliminated the melting problem; it lowered the cost of components, assembly, and wiring, and gave uniform air temperature throughout the full length of the case.



Heater with cold sections solved melting problem at low cost in refrigeration application.

GETTING ALL THE FACTS IS IMPORTANT

Generally, the solution to heater design is not so simple. The application engineer must know all the facts to make the most intelligent recommendation for a specific design.

It is important that we consider:

- Material or solution to be heated
- Operating or process temperature
- Type and amount of insulation
- Heat-up time allowed
- Space available for heater
- Desired operating voltage

Preliminary drawings of the proposed design are especially helpful when they are available.

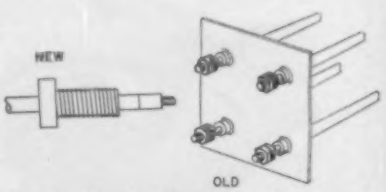
When the application engineer gets all the facts, he can give you the full benefit of his experience, and recommend the best heater for the job. He can recommend the proper sheath material, wattage, number and size of heaters required, lengths and formations, and allowable watts density.

At this point I'd like to emphasize an important fact. You should be sure to give the supplier all the pertinent details which will affect the component design. Every detail is helpful to the application specialist.

TESTING IS A MUST

Once your component heaters have been designed and samples built, the application engineer follows through to make sure they will do the job and give the life you expect. He can suggest procedures so you can do the testing yourself. Or you may want General Electric to test the heaters in your product, or on a mock-up in our lab.

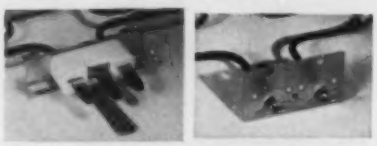
Testing proved its worth last year for one of our customers, a washing machine manufacturer. They were mounting heaters with a plate which was expensive to make and assemble. We were able to meet all their performance requirements by substituting small individual bushings. These passed rigid testing with flyng colors and *saved this customer 20 cents on each heater.*



Individual bushings (left) were substituted for plate-mounting (right), to save 20 cents per heater for a washer manufacturer.

ANOTHER EXAMPLE:

Also in the appliance field, a range manufacturer was using expensive plug-in elements in his ovens to permit removal for cleaning. We reviewed his design, and after testing the new method, suggested hing mounting. This arrangement allowed the elements to be raised for cleaning, and reduced component cost appreciably.



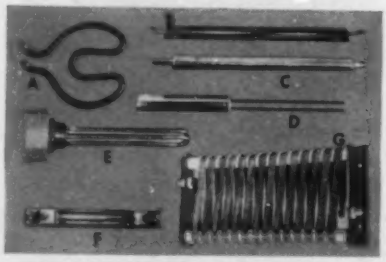
New hinge-mounted element (right) reduces cost for range manufacturer compared to plug-in element (left).

PRICE, DELIVERY, POST-SALE BACKUP

Proper design and application of heaters aren't the only factors your company judges when choosing suppliers. Prices must be competitive; production quantities must be delivered on time; and you expect this product to be backed up with post-sale service and renewal heaters. General Electric has provided this kind of performance to OEM's for many years.

One more thing to remember. Heaters usually represent a small portion of the over-all cost of the product, and contribute substantially to the performance. Saving pennies at the risk of customer complaints, manufacturing rejects, and production delays, can never be the best course.

For help in applying heat to your product or process, please write Section 757-08, General Electric Co., Schenectady 5, N. Y., or call your local G-E Sales Office. And, for a copy of our 48-page catalog of heaters, devices, and heating control, including dimensions, weights, and application tips, tables, and curves, ask for GEC-1005.



High reliability is designed into all General Electric Calrod® heaters: tubular (A); vane (B); finned tubular (C); cartridge (D); immersion (E); strip (F); and oven (G) heaters.

Progress Is Our Most Important Product

GENERAL ELECTRIC

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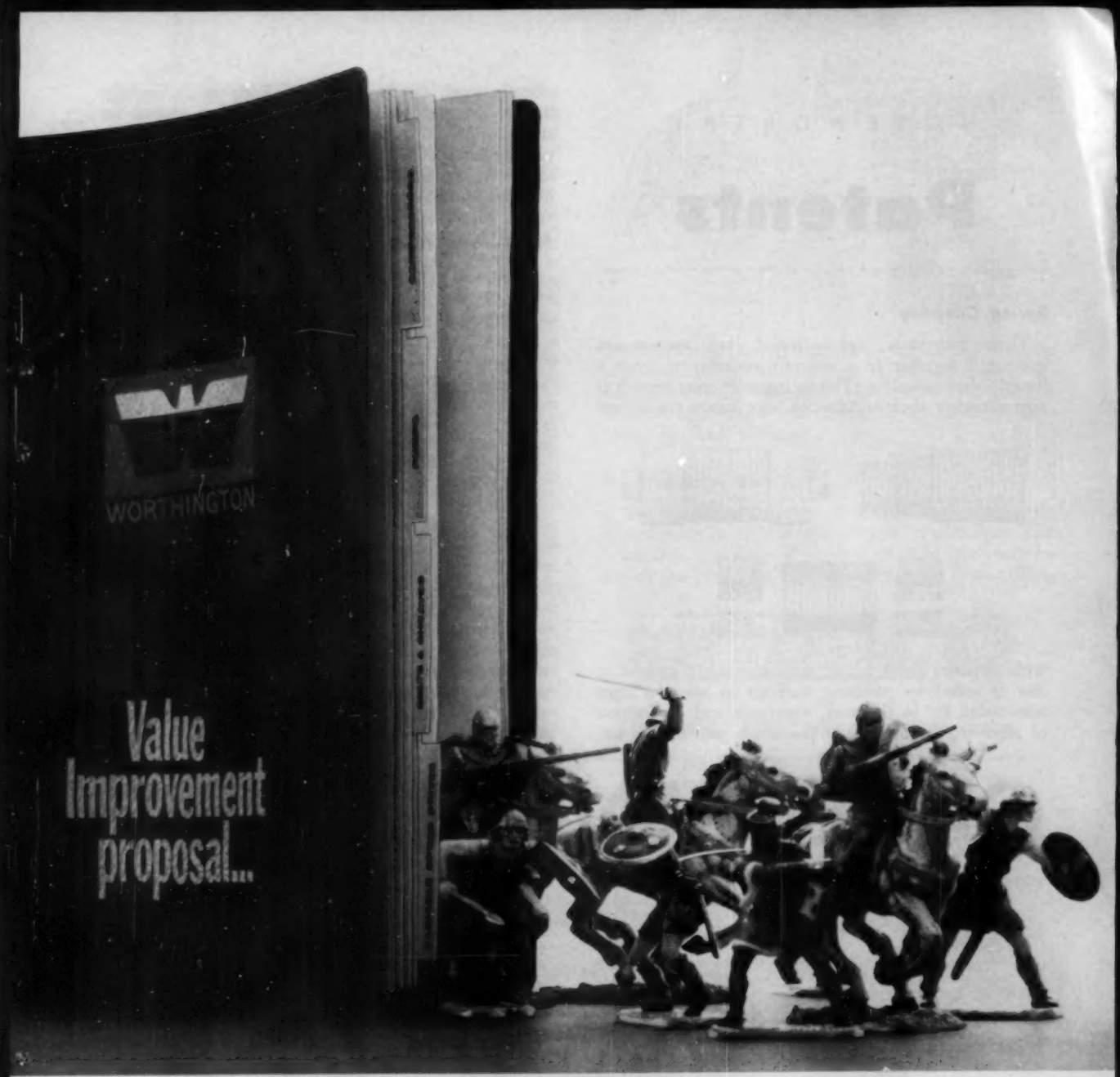

NEW WAY TO ATTACK PRODUCT COSTS...

Now you can be sure that you are getting every last cent from dollars spent on pumps, compressors, mechanical drives and variable speed drives. Worthington's new Value Improvement Program has a minimum of sixteen ways to show you how.

Here's how it works. Under this plan, we will conduct a complete value analysis of the application of pumps, compressors, mechanical drives and variable speed drives in your product. We will review such direct factors as performance, performance flexibility and efficiency. And we will check important indirect factors such as reliability, initial cost, assembly or installation costs, inventory and availability.

The purpose of this Value Improvement Plan is to improve the saleability of your product . . . or its profit to you. After we check at least 16 value analysis points, we will give you our findings and a specific proposal. Then we will follow up with a test unit for your final evaluation.

Why are we so sure that we can help you? We repeatedly face this value analysis in application of our products. And we are fully aware of how to help you get the most value from your purchases under today's market conditions. This our study will confirm . . . or shed new light on your present buying picture.

For additional information about this offer, please ask about our Value Improvement Program. Write to Worthington Corporation, Design Analysis Section, Harrison, New Jersey.

Worthington Corporation, Design Analysis Section, Harrison, N.J.
Please let me know more about your Value Improvement Program.

*Name*_____
*Company*_____
*Address*_____
*City*_____ *State*_____

WORTHINGTON

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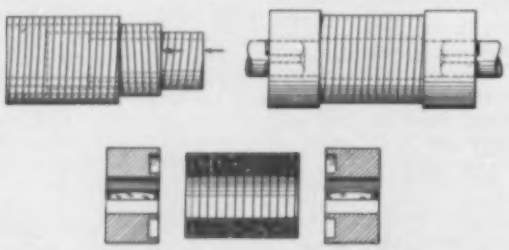
PRODUCTS THAT WORK FOR YOUR PROFIT

NOTEWORTHY

Patents

Spring Coupling

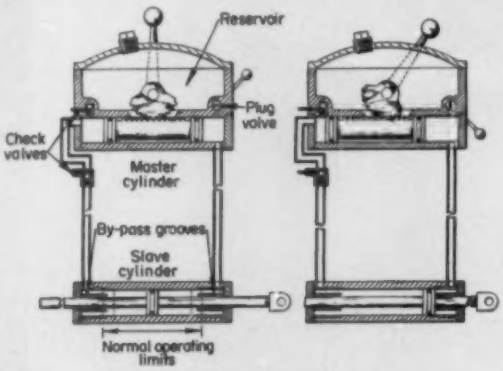
Three concentric, tightly coiled, wire springs are telescoped together in a close-fit assembly to form a flexible shaft coupling. The spring-wire cross section is approximately square. Adjacent wire layers are wound



with opposite hand helixes and are either ground to size or coiled by precision methods to assure a tight telescoping fit. In this way, expansion and contraction of adjoining spring coils is prevented, providing a torsionally rigid, flexible assembly. Ends of the springs fit into terminal sleeves, which are bored to receive the shafts, and are soldered or bonded permanently in place. *Patent* 3,000,197 *assigned to Allpatent Aktiengesellschaft, Vaduz, Liechtenstein by Hans Ruegg, Richard Keller, and Albert Klopfer.*

Self-Purging Hydraulic Circuit

Hydraulic system for remote control of a slave cylinder can be quickly cleared of gases trapped in the working fluid. The system contains a slave cylinder,

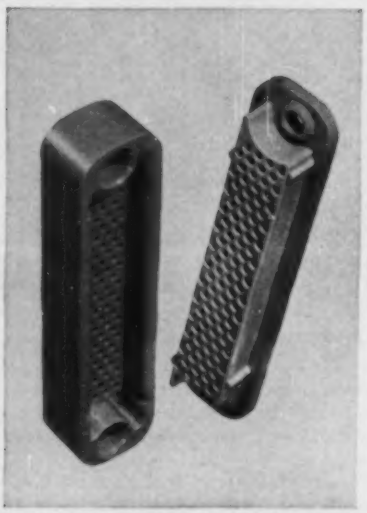


with bypass grooves at each end, and a master cylinder which is connected to the fluid reservoir by a check valve at one end and a plug valve at the other end. Another check valve is located in the supply line to

G-E LEXAN POLYCARB

STRENGTH LEXAN slider for 4-pole switch is 20% glass-filled. The material withstands high impact forces and its flexural modulus is over 1 million psi. Used in rocket sled tests, the filled resin is relatively independent of heat, aging and most environments. It has high melt temperature and excellent electricals. (Atlas Chemical Industries)

IMPROVED FABRICATION. Formerly made of brass, blower couplings for radar unit are now inexpensively vacuum-formed of LEXAN resin, allowing considerable savings in machining costs. Couplings of polycarbonate resin are tough, flame-resistant, give smoother air flow than before. They withstand cycling from —54°C to +54°C under humid conditions. (General Electric)

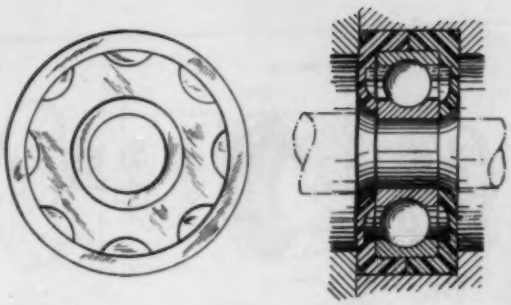


GOOD ELECTRICALS. Microminiature connector contains up to 20% more contacts in the same space, thanks to dimensional stability and good electrical properties of LEXAN resin. Self-extinguishing, the material provides low loss, good insulation resistance and a dielectric constant and power factor which are virtually independent of temperature. (Amphenol-Borg Electronics Corp.)

the slave cylinder. To fill the system the plug valve is opened and the master piston is pumped back and forth, drawing fluid from the reservoir and forcing it through the supply line to drive the slave piston to the right beyond the normal operating position. The mixture of liquids and gases flows around the piston through the bypass grooves and into the return line. Here, the gases are displaced, and flushed through the plug valve into the reservoir for venting. After the system has been purged of gases, the slave piston is returned to operating position, the plug valve is closed, the reservoir check valve is locked in the closed position, and the supply-line check valve is locked in the open position. If gases or vapors accumulate during operation, the pumping procedure may be repeated to purge the system and replenish fluid losses. *Patent 2,997,849 assigned to Outboard, Marine Corp., Waukegan, Ill. by William J. Shimnckas.*

Cushioned Antifriction Bearing

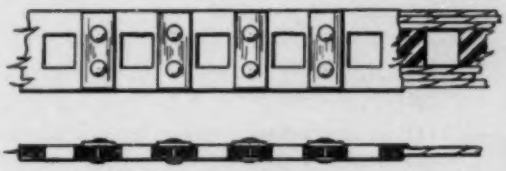
Split plastic casings on ball or roller bearings serve as cushioned support surface and lubricant seal. Made of an elastic, oil-resistant plastic such as polyurethane, the casing halves are seated in the housing under heavy pressure, producing a strong clamping action at the bearing outer race to hold the assembly firmly in place. Sidewalls of the casings carry sealing lips which bear against the inner race under soft elastic pressure to prevent loss of lubricant. Molded-in lugs at the inner face of the sidewalls act as spacers to form a pocket between the bearing and sidewalls for



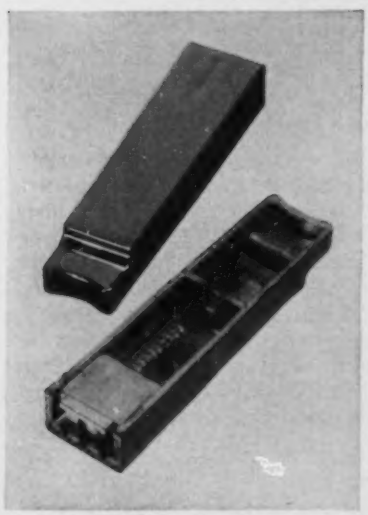
lubricant storage. In operation, the casings insulate the bearing from the housing to minimize transmission of noise and vibration. *Patent 2,986,432 assigned to Wilhelm Herm Muller & Co. K. G., Hanover, Germany by Emil Schlauch.*

Positive-Drive Belt

Reinforced rubber belt is formed with uniformly spaced holes to engage teeth or pins in sprockets. The holes are punched or vulcanized into the belt to match the pitch and form of the sprocket teeth. Com-



ONATE RESIN THE MOST VERSATILE OF THE TOUGH THERMOPLASTICS



HEAT RESISTANCE. Because LEXAN resin can be painted with wear resistant high-temperature bake finishes, it was chosen to replace zinc die castings for auto radio pushbuttons. Base and top coats of these vacuum-metalized parts are baked at 265°F. Buttons are economically injection molded and light in weight . . . make a tight fit on the metal stake. (Motorola, Inc.)

TRANSPARENCY. Face-glass of this pressure gauge is molded of LEXAN 102 — a new, virtually water-white grade of resin. The instrument uses a gray LEXAN back-plate. Transparent LEXAN resin is shock- and heat-resistant . . . replaces glass. The opaque plastic replaces steel or brass. The two injection molded shells form a strong, good looking case. (United States Gauge)

LOOKING FOR THAT EXTRA MARGIN OF DESIGN FREEDOM?

With LEXAN resin you can take down many of the old "proceed with caution" signs. Here is a material with outstanding impact strength! It is metal-like in mechanical properties: strong, hard, stiff, machineable — yet malleable (can be cold formed)! It is dimensionally stable, not only under impact or suddenly applied loads, but also at high temperatures and upon immersion in water. And LEXAN resin makes handsome products — smooth, transparent *or* opaque, colorful. A remarkable thermoplastic!

Don't overlook the design opportunities opened up by LEXAN resin. Send today for details on price, properties, applications and G-E's technical assistance program. Write to: General Electric, Chemical Materials Department. Section MD-12-1, Pittsfield, Mass.

LEXAN®
Polycarbonate Resin
GENERAL ELECTRIC

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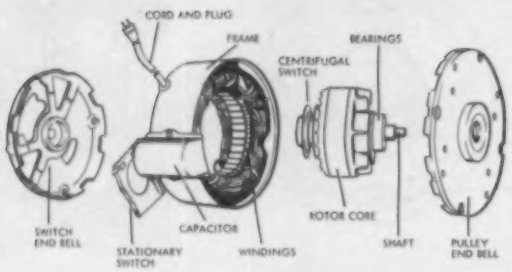

DESIGN YOUR PRODUCT TO DO A JOB.. *NOT TO FIT A MOTOR!*

How will you have **your** motor?

Flattened out slab-thin? Designed for special torque? Submersible? Or invisible? Want it to thrive on "gook"? Or do you just want it to keep **quiet?**

Let us customize a motor to your exact requirements, by modifying any or all of the 11 basic components. The cost is moderate . . . even in moderate quantities.

The brochure shown below will give you a lot of helpful information. It points out how J&H motor elements and characteristics can be tailored to your product envelope, and indicates relative costs for each modification.

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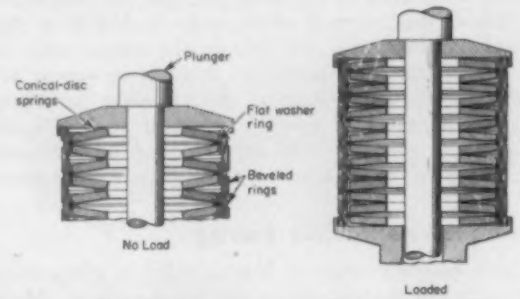
pression plates, which are riveted or bolted together in a sandwich arrangement between holes, prestress the belt material to prevent generation of localized stresses in high-torque service. *Patent* 2,984,120 *assigned to The Gates Rubber Co., Denver, Colorado, by James A. Hurry.*

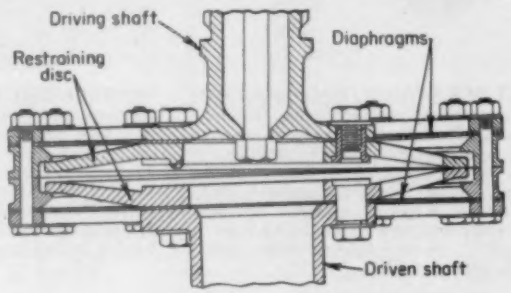


Self-Damping Spring

Beveled rings slide against each other to damp elastic action of a compression spring assembly. The beveled rings, mounted with tapered surfaces in contact, are stacked to form a housing about a number of conical-disc springs which are stacked in a series arrangement. Flat washer rings, mounted in grooves on the inner beveled rings, separate conical-disc spring pairs and synchronize the actions of the spring and beveled-ring columns. When load is applied to the spring assembly, relative sliding motion of the beveled rings produces frictional damping forces and a resilient wedging action. Jamming of the beveled rings is prevented by the conical disc springs, which expand the assembly when load is released. *Patent* 2,999,677 *assigned to Henschel Werke G. M. b. H, Kassel, Germany by Karl Schindler.*

Limited-Misalignment Shaft Coupling

Restraining discs in a flexible coupling assembly prevent connected shafts from exceeding a predetermined angle of misalignment. The conical-shaped discs are bolted at the ID to flanges on each shaft. At the OD, the discs are flattened to form narrow flanges which fit into an annular opening in a bolted ring. Metal diaphragms connect each shaft flange to the ring and serve as the power transmitting elements. In the aligned position, the discs are spaced away from each other and from the walls of the ring opening. When the shafts are misaligned, the discs tilt with



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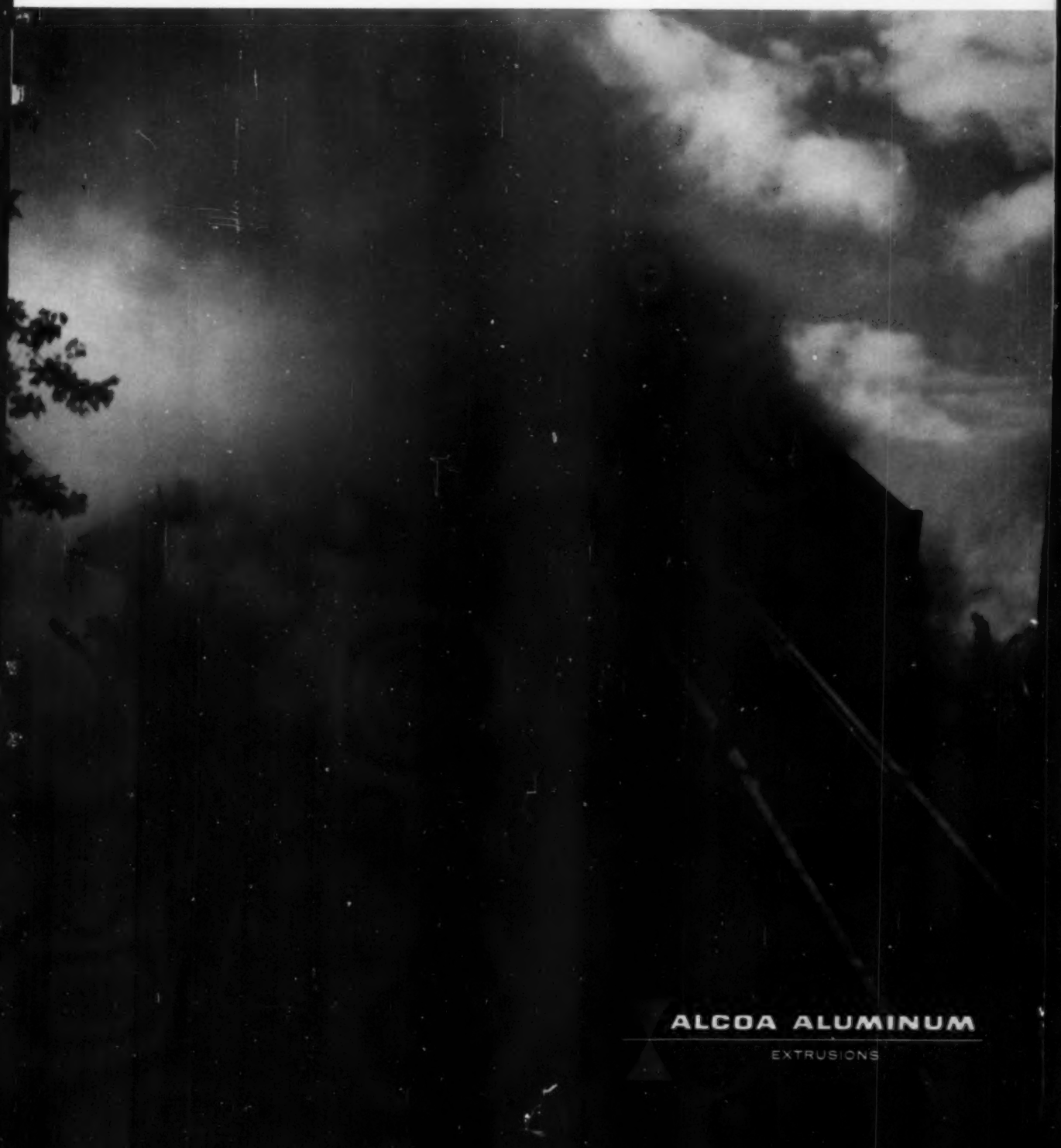
When a 100-ft aluminum ladder stands a 20,000-ft-lb twist...

(Photo courtesy Bureau of Fire, Rochester, N. Y.)



ALCOA ALUMINUM

EXTRUSIONS

When a 100-ft aluminum ladder stands a 20,000-ft-lb twist . . .

that's Alcoa Total Ability at work!

With a 200-lb fire fighter perched at its tip, a 100-ft aerial ladder must stand up to torsional strains as high as 20,000 foot-pounds. Builder Peter Pirsch & Sons Co., Kenosha, Wis., gets the tensile strength of steel—*at one-third the weight*—from Alcoa® Aluminum Extrusions.

Less dead weight means quicker operation and greater safety for the ladder's live load. Its hydraulics cost less, too; pressure is lower, safer. Alcoa Aluminum will never rust, so needs no paint that might blister or peel.

By using metal most efficiently, Alcoa Aluminum Extrusions withstand exceptional stresses for their weight and section. Besides, they can save on machining, joining and assembly. Dies cost little, and Alcoa already has many for standard angles, bars, channels and shapes from H to Z.

Alcoa has turned out more than 150,000 different extruded shapes. We operate two of the world's largest extrusion presses: 14,000 tons. Five plants, coast to coast, make Alcoa the world's largest source of extruded shapes.

We're not only extrusion experts. Alcoa also makes castings, forgings, impacts and screw machine parts. So our only concern is doing your job best at least possible cost. That's how *Alcoa Total Ability* works, from the design on. How can we help you? Find out by calling your nearby Alcoa sales office; or write: Aluminum Company of America, 856-M Alcoa Building, Pittsburgh 19, Pa.

Entertainment at Its Best . . . **ALCOA PREMIERE** with Fred Astaire as Host . . . Tuesday Evenings, **ABC-TV**

ALCOA ALUMINUM

EXTRUSIONS

1. FLATBED TRAILER with extruded Alcoa Aluminum side beams gets almost two tons extra capacity, carrying loads as high as 50,000 lb.

2. UNLOADING BOOM for bulk carrier was made 66 ft longer, weighed 25 tons less after it was fabricated from Alcoa Aluminum Extrusions.

3. CONTINUOUS HINGE has top and body for instrument case extruded in Alcoa Aluminum as integral parts.

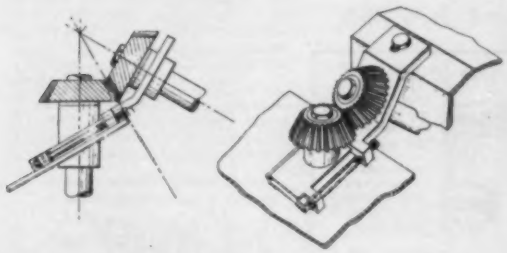
4. RETRACTABLE HYDROFOILS extruded in Alcoa Aluminum lift a 2,000-lb boat clear of the water, nearly double its maximum speed.

5. LOADING RAMPS of Alcoa Aluminum Extrusions easily support a moving load of 2,300 lb, weigh but 5.7 lb per ft.

6. ALCOA UNISTRENGTH* PIPE for mile-long line was welded at one station from 40-ft extrusions, dragged into place across mountains.

*Trademark of Aluminum Company of America

them. At a predetermined angle, the discs come into contact with each other at one point and with the walls of the opening at a point diametrically opposite to block further misalignment. *Patent* 2,997,863 *assigned to The Kaman Aircraft Corp., Bloomfield, Conn. by Walter N. Stone and Nelson R. Richmond.*

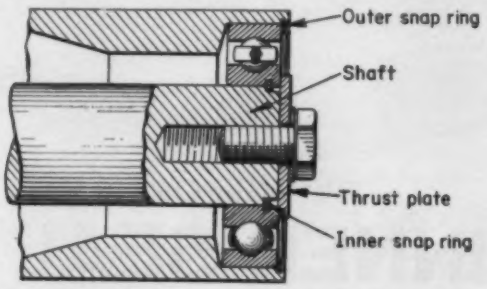


Bevel-Gear Backlash Takeup

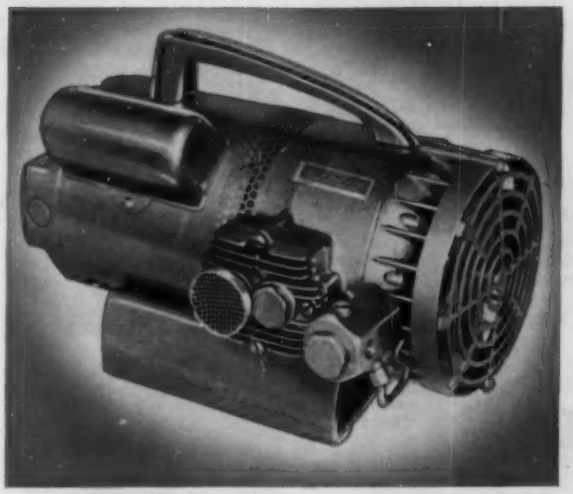
Adjustment of backlash between bevel-gear pairs is accomplished without shims by a sliding-block mounting arrangement. The gears are mounted to two blocks which are fitted together by a dovetail construction to form a sliding connection. Relative position of the blocks is controlled by an adjusting-screw assembly. When the blocks are moved for backlash adjustments, direction of motion is always at right angles to the gears pitch-cone element to maintain correct meshing relationships. *Patent* 2,996,929 *assigned to Orenda Engines Ltd., Malton, Peel, Ontario, Canada, by Gustaw Lazarowicz.*

Rotating-Part Retainer

Parts mounted at the end of rotating shafts are locked against axial movements by a thrust plate and snap-ring assembly. For the antifriction bearing assembly shown, two snap rings are used. One is mounted in the housing bore to retain the outer bearing race and the other is mounted in a groove in the inner bearing race. The inner snap ring engages a shoulder on the



shaft which has a reduced diameter section at the end. The thrust plate is mounted to the end of the shaft by a screw and bears against the inner race of the bearing when drawn up tight to lock the assembly. This arrangement eliminates the need for grooves at highly stressed portions of the shaft, minimizing stress-concentration problems. *Patent* 2,998,988 *assigned to International Harvester Co., Chicago, Ill., by Robert D. Barrett.*



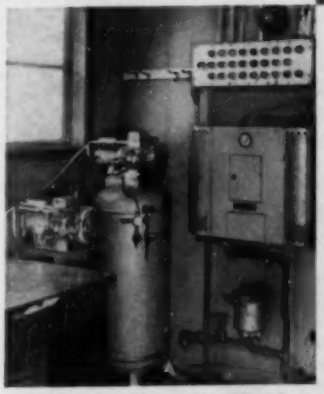
Oil-Free AIR FOR INSTRUMENTATION

For instrument control with compressed air, patented B&G Oil-less Compressors offer outstanding, exclusive advantages.

They deliver air *completely oil-free!* Carbon-graphite piston rings and skirts need no lubrication; bearings are grease-packed and sealed for life. Numerous design and construction features assure dependable delivery of cleaner, cooler, drier air and smoother operation.

B&G Oil-less Compressors can be located at the site of the control, eliminating long pipe lines which may contaminate the air with dirt and condensation.

Available in 58 models... portable, tank mounted, motor and gas-engine driven, 1/12 to 3/4 H.P., up to 6.57 CFM, up to 190 psi. Vacuum: 27.5″.



Typical application to air drier

MINIATURE!

1/12 H.P. Oil-less Motor Compressor and Vacuum Pump

Fits in the palm of your hand, yet delivers much more free air than any current design of the same horsepower. It is capable of continuous operation at pressures up to 65 psi.—has infinite applications for instrument control, process agitation and motive power.

Oil-less AIR COMPRESSORS

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←Circle 368 on Page 19

Circle 369 on Page 19

THE "BIG IDEA"

OFTEN, PROBLEMS OF PRODUCT FUNCTION CAN BE SOLVED WITH AIR PRESSURE OR VACUUM. "AIR MAY BE YOUR ANSWER!"

For the Type, Size, Drive you need— specify

GAST VACUUM PUMPS and AIR COMPRESSORS

On your current design project, consider the benefits Air offers. Applied as pressure or vacuum, it solves many knotty functional problems better than other methods.

It's versatile...easily controllable...and economical. With a small Gast Air Pump, you can provide great force and power. Use air to hold, lift or feed materials . . . to fill or evacuate . . . convey solids or liquids . . . move or reciprocate parts . . . to pressurize, agitate, atomize, oxygenate . . . and for controlling, sampling, testing.

The Gast Line of Air Pumps offers you a wide range for selection. Simple, rotary-vane design is dependable . . . and maintains high efficiency. Air delivery is "pulseless" and quiet. So consider using air on your product—and check with Gast for engineering suggestions.

LUBRICATED AIR PUMPS	OIL-LESS AIR PUMPS
SERVICE. Light-duty, Heavy-duty	SERVICE.....Light-duty
CAPACITIES....0.6 to 50 c.f.m.	CAPACITIES...0.35 to 24 c.f.m.
VACUUM.....To 28" Hg.	VACUUM.....To 25" Hg.
PRESSURE.....To 30 p.s.i.g.	PRESSURE.....To 15 p.s.i.g.
MOTORS.....1/12 to 5 h.p.	MOTORS....1/40 to 1½ h.p.
DRIVES.....Integral-motor, Direct coupled, V-belt	DRIVES.....Integral-motor, Direct coupled, V-belt

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Air Motors • Vacuum Pumps • Compressors

GAST MANUFACTURING CORP.
P.O. BOX 117 P, BENTON HARBOR, MICHIGAN

Circle 370 on Page 19

MOLLY®

JACK NUT

SCREW ANCHOR

The Only Blind Fastener Which Grips Any Material From 0" To ⅜" Thick

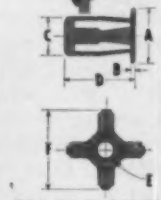
Cuts cost, speeds assembly, solves hitherto impossible fastening problems. Can be used as a rivet and/or blind fastener. It's versatile, easy to use and no special tools are needed.

The only blind fastener with threads which grips any material from 0" to ⅜" thick. Needs only ⅛" expansion space. Allows holes to be fashioned before, during or after fabrication. Hole size is not critical and special type of hole is not necessary.

Made of quality steel, cadmium-plated. Grips evenly on rough as well as smooth surfaces. Provides vibration-proof assembly. Weight-carrying capacity is limited in most cases only by strength of the material in which used.

EASY TO INSTALL

1. Insert anchor into hole. Needs only ⅛" expansion space.
2. Run in screw to collapse spider anchor backing by exerting pull on threads.
3. Anchor now is installed and ready to receive attachment screw.



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MOLLY® CORP.
230M N. 5th St., Reading, Pa.

SPECIFICATIONS

CAT. NO.	A CAP DIA.	B CAP THICK.	C BODY DIA.	D O'ALL L'NTH.	E THREAD	F MAX. SPHEAD
6-S, JH	15/32	3/64	9/32	9/16	6-32	43/64
6-L, JH	15/32	3/64	9/32	3/4	6-32	43/64
*6-S, JH	17/32	1/16	3/8	11/16	10-24	25/32
6-L, JH	17/32	1/16	3/8	7/8	10-24	25/32
**8-S, JH	5/8	1/16	27/64	3/4	¼"-20	13/16
8-L, JH	5/8	1/16	27/64	15/16	¼"-20	13/16

*8-32 and 10-32 threads available
**10-24 and 12-24 threads available

Also available in brass and stainless steel

Circle 371 on Page 19

Seals best...Protects best

FREE

SAMPLES and FACT FOLDER FOR DESIGNERS and ENGINEERS

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INNER-SEAL®

RUBBER SEALING STRIP

Made of resilient sponge rubber locked into flexible spring steel flange, covered with oil and water-resistant Neoprene*. Assures a close-fitting seal that is air-tight, sun-tight, resists cold and heat. Easy to install, conforms to any shape, stops rattles, quiets slamming, absorbs shocks. Used for aircraft, hatch covers, shipping cases, refrigerated trucks, artificial lungs, generators, cushioning.

Write Dept. MDI2

**Reg. T.M of DuPont*

BRIDGEPORT FABRICS, INC., Bridgeport 9, Conn.

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COMFORTABLE, UPHOLSTERED, ADJUSTABLE DRAFTING CHAIRS

- 2 inch upholstered seat
- Full swivel seat
- 2-way adjustable tempered steel folding backrest
- No soiled hands when adjusting seat
- Three sizes: 20" to 28" — 24" to 32" — 28" to 36"
- Gray, green, beige or brown finish

Also available with round metal or wood seat; or formed plywood or solid hardwood saddle seat.

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Use an AJUSTRITE chair or stool for 30 days without obligation. Write today—we'll do the rest.

10 YEAR GUARANTEE

32 Models for Factories • Schools • Laboratories • Hospitals • Offices

AJUSTRITE CHAIRS ... STOOLS

AJUSTO EQUIPMENT CO.
Bowling Green, Ohio

Circle 373 on Page 19

SPEED SELECTOR **VARIABLE SPEED DRIVES and SHEAVES**

New
ADJUSTABLE MOTOR BASE

Most efficient and accurate variable speed drive—¾ hp. to 10 hp. Low cost, easily installed, little or no maintenance. Check its many advantages!

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VARI-PITCH SHEAVES

can give your machines wide-range speed control on fixed centers—ratios up to 8:1—capacities from ¼ hp. to 10 hp. Used by many industries in a variety of applications. Rugged, efficient, economical, simple to use.

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SPEED SELECTOR INC.
P.O. BOX 312-B • CHAGRIN FALLS, OHIO

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GET *IMMEDIATE* ANSWERS WITH YOUR OWN **Dillon** TESTING DEPARTMENT!

DYNAMOMETERS

UNIVERSAL TESTING MACHINES

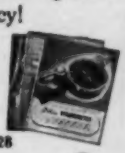
REMOTE-INDICATING LOAD CELL SYSTEMS

PROFESSIONAL Testing Equipment Within Reach of the Average Shop Budget!

Your own *available* test department can be worth its weight in gold. In addition to getting *immediate* answers to your problems, you'll save outside fees...and costly employee waiting time.

Whatever your product, there's a Dillon instrument you can use to advantage. Tensile, compression, torque or shear ...1 pound to *1 million* pounds! Anyone can operate. Rugged and dependable. Guaranteed accuracy!

PLEASE BE SURE TO MENTION PRODUCT IN WHICH YOU ARE *SPECIFICALLY* INTERESTED. A COPY OF OUR *GENERAL* CATALOG ON *OTHER* DILLON PRODUCTS WILL BE INCLUDED.



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Representatives in All Principal Cities

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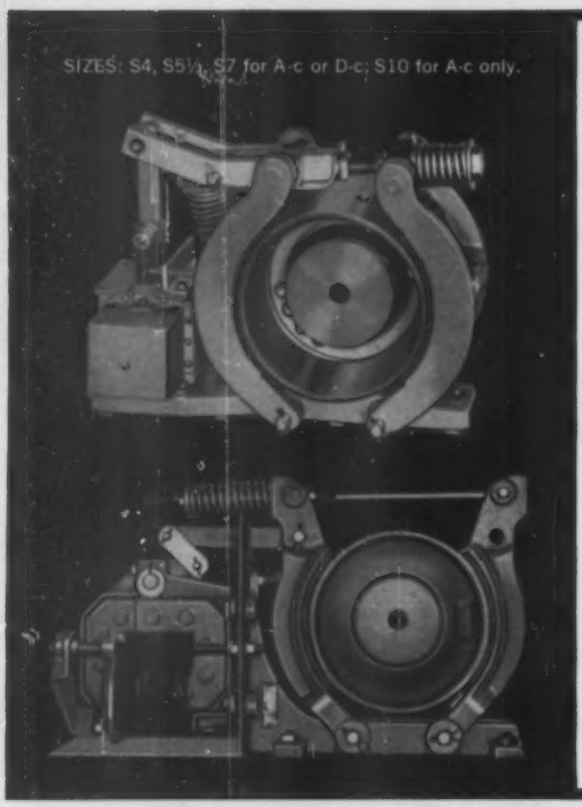

CONTROL

Here are the brakes that assure longer life

Cutler-Hammer A-c & D-c Solenoid Operated

Best brakes you can buy for conveyors, machine tools, elevators, small cranes and hoists and similar applications requiring a small dependable brake for stopping or holding the load.

Brake operates on extended motor shaft or may be applied to intermediate shafts of the transmission system.

Brake wheels are relatively large for torque developed, permitting greater amount of friction lining and lower brake shoe pressure. Payoff: Even wear of friction surface means longer life.

For more information, call your local sales office or write for Bulletin 511-Y243.

WHAT'S NEW? ASK...

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Cutler-Hammer Inc., Milwaukee, Wisconsin • Division: Airborne Instruments Laboratory • Subsidiary: Cutler-Hammer International, C. A. • Associates: Cutler-Hammer, Canada, Ltd.; Cutler-Hammer, Mexicana, S. A.

Circle 376 on Page 19

MAYLINE

Adaptable Drafting Furniture

METAL PLAN FILE

Mayline 5 Drawer Metal Plan File can be attached to a Mayline May-O-Matic drafting table. A file mounted on a table gives 5 drawers extra of filing space.

The May-O-Matic drafting table is entirely adjustable and counterbalanced. Has sliding reference top. Seven combinations available. For complete details on both products ask your dealer for folders S-20 and S-23.

MAY-O-MATIC "E" COMBINATION

MAYLINE CO., INC.

601 No. Commerce St.

Sheboygan, Wisconsin

MAYLINE

MAYLINE

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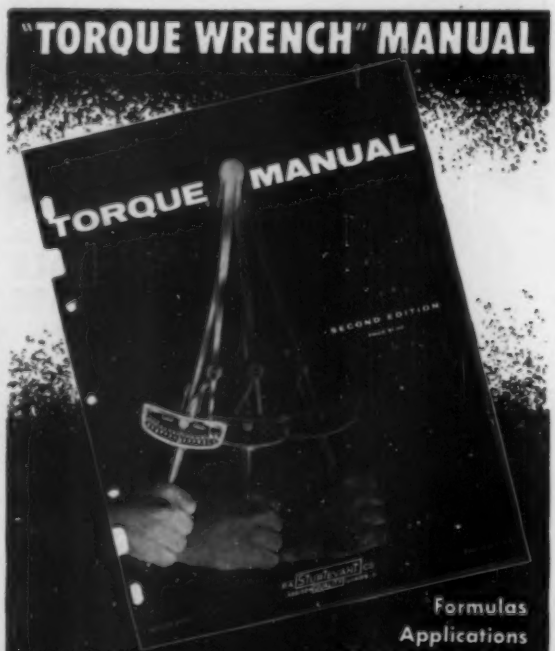
"TORQUE WRENCH" MANUAL



SENT UPON REQUEST

Formulas
Applications
Engineering Data
Screw Torque Data
Adapter Problems
General Principles

PA STURTEVANT CO
ADDISON QUALITY ILLINOIS

Manufacturers of over 85% of the torque wrenches used in industry

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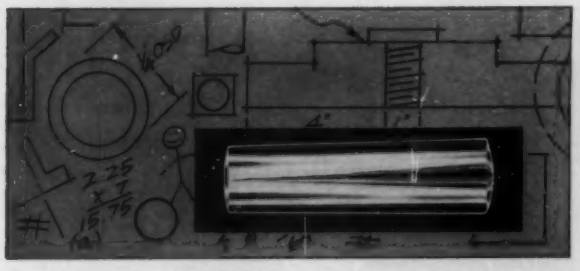


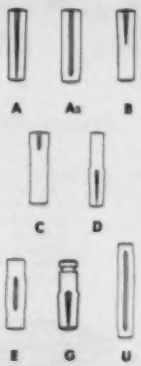
DON'T DISPOSE OF DOODLES

if they pertain to fastening problems

Next time you're sketching out a problem, give Driv-Lok a crack at it. We can pin down quite a bit of helpful information from a doodle.

We'd like to know what the application is, dimensions, metals used, and any pertinent factors such as shock or vibration, corrosion, electrical properties... the things needed to let us give you a proper pin recommendation and a price.

Driv-Lok's wide variety of grooved pins and agile engineering ability have solved a multitude of fastening problems. We'd like a chance at yours.



8 STANDARD TYPES PLUS SPECIALS in a variety of metals. Send for your free catalog and samples, too.

DRIV-LOK SALES CORPORATION

715 PARK AVENUE • SYCAMORE 4, ILLINOIS

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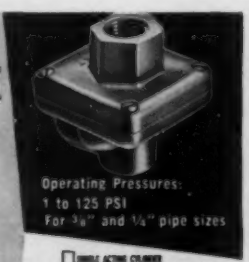
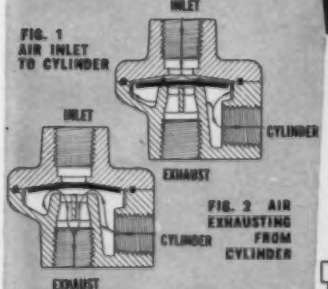
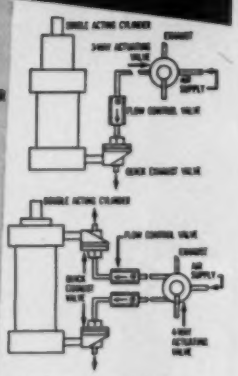
NEW! Pneu-trol® QUICK EXHAUST VALVE

Fast air dumping AT THE CYLINDER permits use of smaller valves and piping . . . INCREASES EFFICIENCY AND SPEEDS





When control valve is opened air pressure seals exhaust port and diaphragm is deflected permitting air to pass thru the cylinder port (Fig. 1). When inlet pressure is relieved (by actuating valve in control circuit) the buildup of cylinder return pressure closes inlet port (Fig. 2) snapping the diaphragm off the exhaust port allowing instantaneous evacuation of exhaust air. *Write for complete details, specifications and prices.*



TYPICAL APPLICATIONS of Quick Exhaust Valves in Single and Double Acting Cylinders. Because exhaust air is dumped at cylinder, smaller diameter piping and smaller selector valves can be used.

AUTO-PONENTS INC.

2925 Grant St. • Bellwood, Illinois

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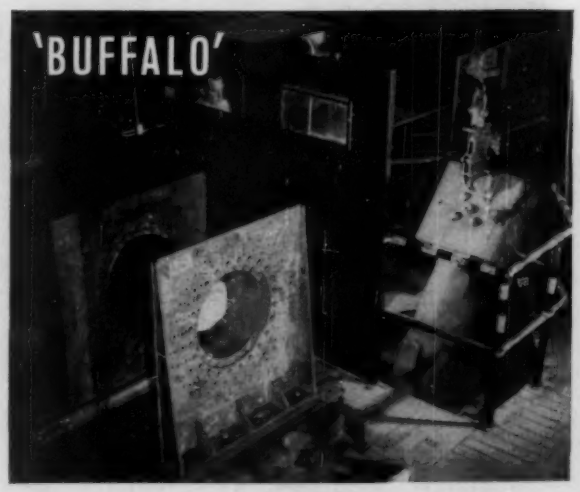

VANEAXIAL FAN DEFIES

HIGH IMPACT SHOCK TEST... at G.E.

Shown above is a 'Buffalo' Vaneaxial Fan undergoing severe MIL-S901 test at General Electric. Six times, the 3000 lb. hammer (upper right), attached to a 5' pendulum, smashed downward... striking test platform from underneath with a many-ton jolt. Operating fan and motor, subjected to accelerations in excess of 1000 g's, remained in excellent running condition.

In construction and design, the fan above is typical of the complete 'Buffalo' line of Vaneaxial and Tubeaxial fans which includes 22 models... capacity ranges from 2000 to 65,000 cfm's. These fans, in 4 and 7 blade models, are designed for high static pressures (up to 17") while operating economically and efficiently at slower than usual speeds.

Steel, die-formed blades which change in pitch from hub to tip, assure *uniform* flow of air over the entire blade. Air foil blades as well as steel, cast alloy, and non-sparking aluminum wheels are available. Variable pitch blades... direct and belt driven arrangements can be furnished when the application requires.

More than 120 leading manufacturers are already using 'Buffalo' air and liquid handling equipment to help make the products they design perform as specified. For detailed information on fans, air conditioning units, and pumps call the resident Buffalo representative nearest you, or write our home office direct.

"Buffalo"

AIR HANDLING DIVISION

BUFFALO FORGE COMPANY

Buffalo, New York

Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

'Buffalo' Air Handling equipment to move, heat, cool, dehumidify and clean air and other gases.

'Buffalo' Machine Tools to drill, punch, shear, bend, slit, notch and cope for production or plant maintenance.

'Buffalo' Centrifugal Pumps to handle most liquids and slurries under a variety of conditions.

Squier Machinery to process sugar cane, coffee and rice. Special processing machinery for chemicals.

Circle 381 on Page 19

NEW

Series "A"

Heavy Duty
High Speed

INDEX TABLE

by CMC

The one unit that does bigger jobs better . . . Series "A" High Speed Index Table is quality to the highest standards . . . provids extreme accuracy of .001 on a 28" diameter . . . efficiently handles loads of 24,000 inch pounds, and over, with outstanding accuracy and maintains zero backlash in dwell position with a high-speed jerk-free operation . . . enables designers to make full use of modern high speed equipment.

With the New Series "A" Index Table You Get:

- Timken bearing near outside diameter of cam follower plate for greatly increased stability
- Supports dial plate load of 18,000 lbs.
- Machined housing surface for mounting tooling plate and permitting shaft mounted speed reducers to be fitted direct
- Immediate adaptability to dial plate of your choice
- Hollow output shaft enables air, fluids, coolants or additional tooling to be brought directly to center of work area
- Hardened, MACHINE GROUND tool steel cam; precision bearings; MACHINE GROUND critical components

QUALITY • VALUE • PERFORMANCE
FOR A NEW HIGH IN SATISFACTION

Complete and informative literature and engineering data available upon request. Send for it today.

COMMERCIAL CAM & MACHINE CO.
455 N. Artesian Ave. • Chicago 12, Ill.
Established 1921

CMC

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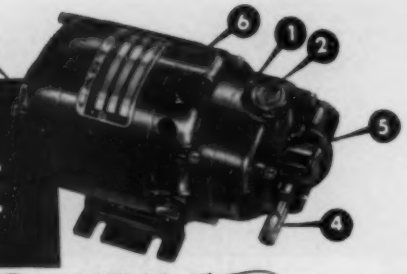
NEED A CHANGE ?



The NEW Classic TM

GEARMOTORS

are Designed to Fit Your Needs

1. SINGLE OR DOUBLE reduction, shaft speeds 2 to 750 RPM, up to 7 in. lbs. torque, available in same gear housing.
2. SPECIAL GEAR combinations and materials available.
3. ARMATURE SHAFT EXTENSION available.
4. SHAFT LENGTH variable to specification.
5. 12 SHAFT POSITIONS available by relocating 3 screws.
6. VENTILATED or totally enclosed as required.

Carter Classic Gearmotors give you the mass production economies of "standard" models, yet can be custom-modified to meet your needs without the penalizing cost of a "special" job. Interchangeable with most competitive types, too. Quality built for top performance. 50 catalog models. Hundreds of variations promptly available. Series motors 6 to 220 v., DC shunt motors 6 to 115 v. Classic motors, less gear reduction, available in 1/40 to 1/7 hp.

Write for new catalog 561 A, prices, OEM discounts.
Use letterhead for special attention

Carter Motor

Carter Motor Company
2719 W. George St. - Chicago 18
Phone JU 8-7700

Large enough to Serve You — Small enough to Want to.

Circle 383 on Page 19

UNLIMITED
MANIFOLD MOUNTING
OF VERSA SERIES "A" SOLENOID VALVES

WITH VERSA

Co-Ordinates

■ Now...You can mount an unlimited number of Versa Series "A" Solenoid Valves as one integrated unit with these new Versa Co-Ordinate Assemblies. These assemblies make possible simplicity of design in both Hydraulic and Pneumatic operation, because only one inlet is required to feed the entire line of valves. Additional blocks can be added at any time and blocks with and without adjustable built-in bleed controls can be used together in one unit. ■ Combined with Versa Series "A" Valves these Co-Ordinates provide the most flexible and reliable Multiple Solenoid Valve Assemblies in the Control Valve field. Write for Bulletin # 960.

VERSA Valves

VERSA PRODUCTS COMPANY, INC.
150M Coolidge Ave., Englewood, N. J.

Circle 384 on Page 19

"Dyflon"®

Self-Aligning and Self-Lubricating SPHERICAL BEARINGS

Combine "Monoball"® Engineering Advantages with Life-Time Lubrication

Design engineers in many industries are specifying new "DYFLON"® SELF-ALIGNING and SELF-LUBRICATING SPHERICAL BEARINGS for these 5 major reasons:

1. **LOWER COEFFICIENT OF FRICTION** ...ideal where lubrication is impossible or undesirable.
2. **WITHSTAND EXTREME VIBRATION** ...perfect performance under shock load conditions.
3. **WILL NOT "COLD-FLOW"** ...even under extreme load conditions.
4. **IMPERVIOUS TO KNOWN CHEMICAL SOLVENTS** ...eliminates corrosion problems.
5. **FAIL-SAFE** ...due to "Monoball"® design.

Request Engineering manual No. 551.

In addition, due to their two-piece "MONOBALL"® design and plastic alloy insert, "DYFLON"® bearings have a long cycle life. Alignment and installation problems are minimized. Oil-free for life means lowest possible maintenance costs.

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"ALARM-TYPE" FLOW INDICATOR WARNS OF ABNORMAL FLUID FLOW

New, weatherproof, reliable device costs $50.00 F.O.B. Cornwells Heights . . . Flow ranges 0.05 to 10 gpm . . . Vibration proof switch for high or low settings . . . Switch can be used directly or through relay to activate alarm devices or perform "start-stop" functions. Request data or order direct from—

SK Type 1885-CDA "FLO-EYE" Indicator Alarm. ½" N.P.T. Connections. Pressure rating 125 psig (standard unit).

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EXPORT DEPT.: 1505 Race Street, Philadelphia 2, Pa., U.S.A.

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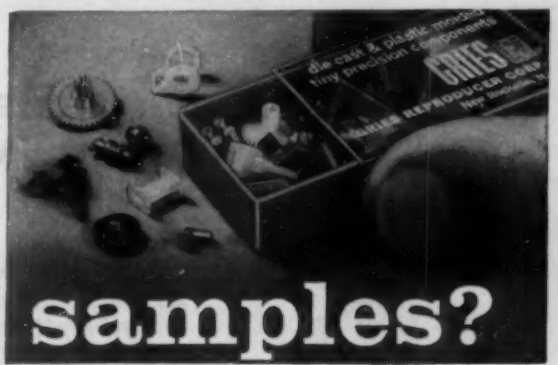

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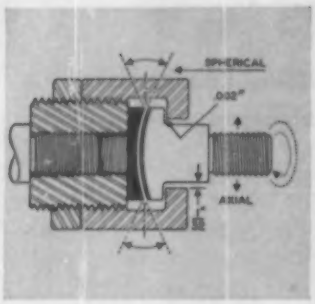
NEW SELF-ALIGNING ROD END COUPLER

Spherical movement (on push only) and radial movement provide precision alignment between cylinder and machine. Couplers shipped with .002" clearance between floating head and shoulder of retaining nut.



- Reduces cylinder bearing wear caused by side loads and binding
- Compensates for machinery deflection due to weight shifts
- Saves cost and time of custom-designing special assemblies
- Allows greater machinery tolerances
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- Fits all air and hydraulic cylinders built to industry standards
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- Immediate delivery from stock of couplers for 5/8, 1, 1 3/8, 1 3/4, 2, and 2 1/2-inch diameter rods. Also available for 3, 3 1/2, 4 1/2, and 5 1/2-inch rods.

HYDRO-LINE **HL**

5602 PIKE ROAD, ROCKFORD, ILLINOIS manufacturers of: high- and low-pressure hydraulic cylinders • heavy-duty air cylinders • adjustable-stroke cylinders • dispensing cylinders • intensifiers • single-acting cylinders • booster cylinders

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NEW! WORM GEAR SCREW JACKS by JOYCE

For...
Pressure and Torque Applications
Actuating
Conveyor Adjustments
Machine Adjustments
Leveling Systems
Welding Positioners
Jigs
Testing Equipment

Models, one ton and up. Can be driven by motors or manually operated . . . synchronized by interlocking shafting and gear boxes. Various screw attachment heads available . . . also stainless steel or hollow screws.
SEND COUPON FOR FOLDER TODAY!

JOYCE JACKS

THE JOYCE-CRIDLAND COMPANY, DAYTON 3, OHIO
Rush folder on Worm Gear Screw Jacks!
NAME_____
COMPANY_____
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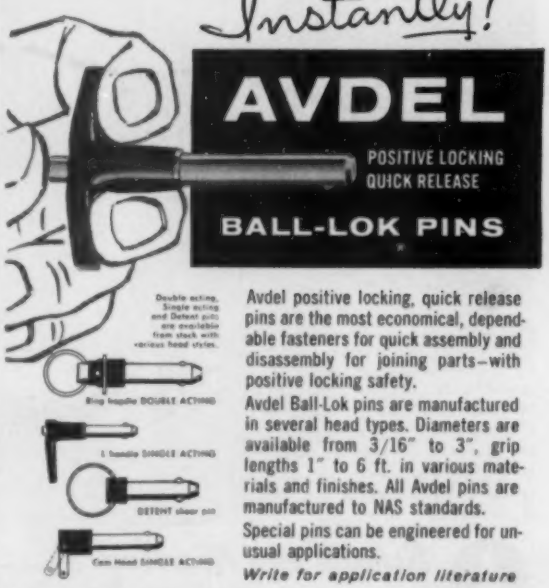
to SECURE IT... to RELEASE IT Instantly!


AVDEL
POSITIVE LOCKING
QUICK RELEASE
BALL-LOK PINS
Double acting, Single acting and Detent pins are available from stock with various head styles.
Ring handle DOUBLE ACTING
T handle DOUBLE ACTING
DETENT sheer pin
Cam Head SINGLE ACTING

Avdel positive locking, quick release pins are the most economical, dependable fasteners for quick assembly and disassembly for joining parts—with positive locking safety.

Avdel Ball-Lok pins are manufactured in several head types. Diameters are available from 3/16" to 3", grip lengths 1" to 6 ft. in various materials and finishes. All Avdel pins are manufactured to NAS standards.

Special pins can be engineered for unusual applications.

Write for application literature

AVDEL INC. 210 SO. VICTORY BLVD., BURBANK, CALIF.
TORONTO, CANADA • HERTS, ENGLAND • GENEVA, SWITZERLAND

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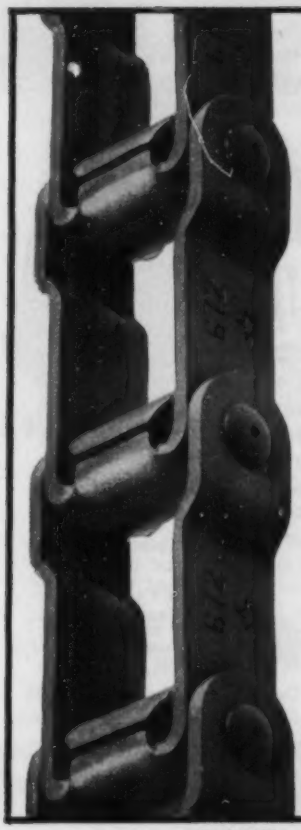

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THE LOCKE STEEL CHAIN COMPANY HUNTINGTON, IND.

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Let our engineers with more than a decade in gear experience consider your gear problems DURING the design process — send blueprints or specs for prompt estimates.

Gears made only to your specifications. None carried in stock.

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PROCESS GEAR CO., INC.

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for heavy duty industrial applications

Mounts in 1" clearance hole

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DISCS with legends, behind flat lenses, deliver specific messages.

NO OIL, WATER, DUST or FUMES CAN PENETRATE THE *Built in* BARRIERS

(Illust. approx. 60% actual size)

Mounts in 1" clearance hole

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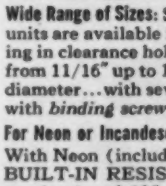

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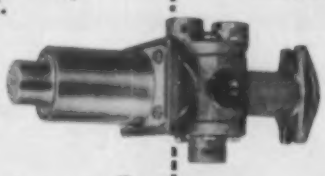

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BPA NEP

backtalk——

—Outlook: Way Out

One of our editors who is on the mailing list for reports from the National Aeronautics and Space Administration points out how the pace of technological change is documented in these writings. One day's mailing of Technical Notes, for instance, consisted of the following titles: "Density in a Planetary Exosphere," "Velocity Requirements for Abort from the Boost Trajectory of a Manned Lunar Mission," "On the Long Period Luni-Solar Effect in the Motion of an Artificial Satellite," "On the Electron Density Distribution Above the F2 Peak," and "Simple Formulas for Stagnation-Point Convective Heat Loads in Lunar Return."

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Entries must be production parts made after March of this year, and the contest closes March 1, 1962. Entry blanks can be obtained from C. R. Maxon, New Jersey Zinc Co., 160 Front St., New York 38, N. Y.

—Not To Be Sneezed At

Anyone continually exposed to current technological developments and wondrous inventions (as we are) shouldn't be surprised at anything. But every once in a while along comes a device that causes our eyes to widen and our lips to murmur "What next?" This time it's a labor-saving gadget—an automatic grinder for fresh pepper. Billed in one advertisement as a "cordless electric pepper mill," it's a wooden affair, tall enough to hold three flashlight batteries. All the gourmet does is press the top and fresh-ground pepper falls out the bottom.

This gives us a what-next idea: How about a companion piece—an automatic salt dispenser, perhaps utilizing the aerosol principle?

—Power Source

Sometime during the fortnight between the arrival of this issue and the next one, you will receive another fine MACHINE DESIGN product—the *Electric Motor Book*, fifth volume in our reference manual series. Following the format of its predecessors, the *Electric Motor Book* will consist of Design Data and Product Directory sections. Its nineteen chapters will discuss all kinds of motors: Induction, synchronous, dc, ac and dc integral horsepower, fractional horsepower, multispeed, instrument, servo, special-purpose, timing, torque, and gearmotors. Driven machine mechanics, motor temperature and insulation, thermal protection, bearings and lubrication, enclosures and mounting are also covered editorially.

Handy listings in the Product Directory will tell where you can obtain fractional-horsepower motors, integral-horsepower motors, definite-purpose motors, and special motors and motor thermal protectors.

As is our custom in book-making, we're printing lots of copies. Extras will be available for $2 from Reader Service, MACHINE DESIGN, Penton Bldg., Cleveland 13, Ohio.

Happy motoring.

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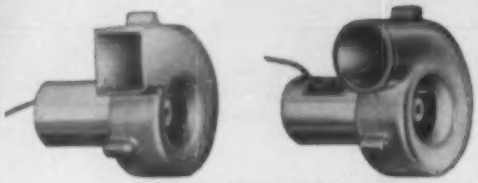

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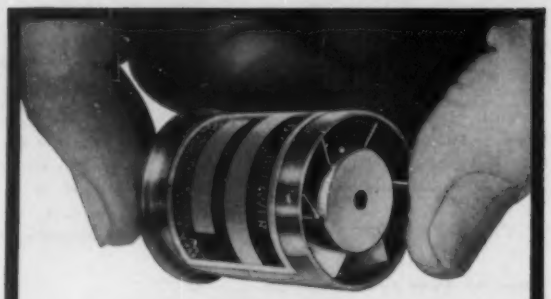

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VAX-1-DC blower operates on 28 v.d.c. or less, using a maximum of 200 milliamps. Weight is 1.4 ounces. Mounts with standard servo ring clamps. (Globe makes larger blowers also.) Request Bulletin VAX-1 from Globe Industries, Inc., 1784 Stanley Avenue, Dayton 4, Ohio.

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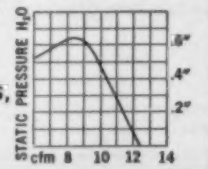

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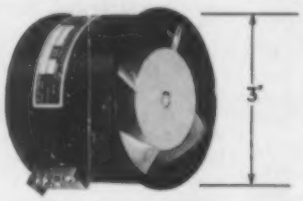

NEW 3" BLOWERS a.c. or d.c.

Globe's new 3" diameter VAX-3 vaneaxial blowers combine the ultimate in low weight and small size with high performance at high back pressures.

VAX-3-FC. Designed for 100 cfm. @ 3.5" H_2O back pressure, unit operates on 115 or 200 v.a.c., 400 cycle, 3-phase. Variable speed high altitude units available. Length is 2⅜"; weight is 14 oz. Servo clamp mounting. Designed for MIL specs.

VAX-3-BD. Designed for 80 cfm. @ 1.2" H_2O back pressure, unit operates on 28 v.d.c., but other versions may be wound for up to 115 v.d.c. operation. Length is 3¼"; weight is 16 oz. Servo clamp mounting. Designed for MIL specs.

VAX-3-GN. Same performance as BD version. 115 v.a.c., 60 cycles. Can operate on d.c. also. 3¼" long.

Request Bulletin VAX-3 from Globe Industries, Inc., 1784 Stanley Avenue, Dayton 4, Ohio.

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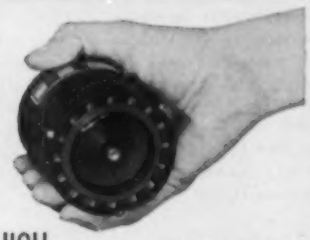

NEW HIGH PRESSURE BLOWER

miniature a.c. multi-stage

New Globe multi-stage blowers are to replace blowers up to ¼ hp in cooling applications where high back pressure is the big problem (heat exchangers, crowded circuits, etc.). STAX-3-FC delivers 45 cfm against 14" H_2O back pressure (65 cfm free air). Low specific speed (Ns=15,000) is the secret of this outstanding performance. Units use 200 v.a.c., 400 cycle, 3 phase power, and are designed to meet MIL specs, including 50 G's vibration and 1000 hr. life. Three-stage unit weighs 29 oz.; one and two-stage standard units available also. Production tooling keeps the cost within reason. Some units stocked for 24-hour prototype delivery. If you need more performance or different power, etc., Globe will design the exact blower you need. Request Bulletin STAX from Globe Industries, Inc., 1784 Stanley Avenue, Dayton 4, Ohio.

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Western BRASS

(Before)

Olin BRASS

(After)

The letterheads have been printed, signs made... and here we are wearing a new name. But in the mills things go on pretty much as they always have. We've put in some new machines and broadened our line... but essentially it's the people at Western (oops!) *Olin* Brass that really make the product. They *care*. That's the "Tailor-Made" approach.

If you're an old customer you know what we mean. If you're not – ask one of our users. Chances are he'll tell you the uniform quality and individual engineering of his metal has managed to save him money in inspection, fewer rejects and less lost time.

Olin Brass can do the same thing for you.

We're the same folks.

(Brass sales headquarters at East Alton, Illinois)

METALS DIVISION Olin
400 Park Ave., New York 22, New York.

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C/R®

DESIGN NOTES

C/R offers new bonded CRS Seal design in standard sizes — without premium tooling charges

Design Advantages

The CRS Seal now provides a new level of C/R Seal performance through its simple, bonded design. There are no internal parts to misalign, no avenues for internal leakage. The shell and sealing member are integral — bonded securely for the long life of the seal. The CRS Seal incorporates a sealing member with both improved lip configuration and improved concentricity. The sealing member has been strengthened over former designs by placing more material at points of major flex and wear — and without increased shaft loading.

Designer Advantages

The CRS Seal gives the designer one, basic, rugged shaft seal design which may be applied with high reliability to the great majority of common shaft seal applications — particularly in industrial, automotive, farm, and off-the-road equipment.

Four basic design variations are available. As you can see, these provide an auxiliary sealing lip, where it may be required, or provide extra rugged shell construction where conditions suggest the need to protect the seal lip against assembly damage — or where large, heavy-duty shafts are being sealed.

Selection of the new C/R Type CRS Seal gives the designer and buyer major advantages over special seals: shorter lead time on orders, simpler specification, savings in time and money, and improved assembly quality and reliability.

Operating Maximums*

Shaft Speeds	3600 fpm (single lip) 2500 fpm (double lip)
Run-out	.015" TIR dynamic eccentricity .010" static eccentricity
Temperature	−30 to +275°F. (225°F. in EP lube)
Pressure	5 psi (single lip) 10 psi (double lip)
Media	Oil, grease, fuel, water

Not all conditions present in one application

New, Improved Compound

Standard sealing members for the C/R Type CRS Seal are molded of a new Sirvene synthetic rubber compound having markedly superior sealing and wearing properties. It is a Buna-N-based material with low-friction characteristics. The CRS Seal can also be furnished in the usual special materials such as acrylates, Silicones, and butyls. Shells are of standard steel, but can be provided in corrosion-resistant materials on special order.

Consult C/R Engineers

For assistance on the application of the new CRS — or on any oil seal problem, get in touch with C/R Oil Seal Engineers. They're specialists in fluid sealing — and will gladly cooperate with you.

For More Design Data:

You will want the complete design data on the new CRS Seal. Write for our Bulletin CRS-100. It gives you the complete list of standard sizes, widths, O.D.'s, shell thicknesses and sealing lip heights. You will want it to compare and then specify C/R's CRS Seal.

CHICAGO RAWHIDE MANUFACTURING COMPANY

1221 Elston Avenue • Chicago 22, Illinois

Offices in principal cities

See your telephone directory

In Canada: Chicago Rawhide Mfg. Co. of Canada, Ltd., Brantford, Ontario

Export Sales: Geon International Corp., Great Neck, New York

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